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CERTAIN VASCULAR ABNORMALITIES OF THE LUNGS*

HICKEY LECTURE, 1961

By C. ALLEN GOOD, M.D., *Section of Roentgenology, Mayo Clinic and Mayo Foundation*
ROCHESTER, MINNESOTA

The Hickey Memorial Lecture was established to honor the memory of a man who was one of the pioneers in the specialty of roentgenology, one of the leaders in its development and one of the best-loved teachers of its principles. Preston M. Hickey was born in Michigan, educated in Michigan, practiced in Michigan and spent the last twenty-one years of his life as professor of roentgenology in Michigan, first at the Detroit College of Medicine and Surgery and later at the University at Ann Arbor. After his death in 1930, at the age of sixty-five, it was said of him, "He will be remembered in many capacities . . . as a fellow radiologist, teacher, investigator, inventor, physician, diagnostician, writer, editor, soldier, administrator, advisor and friend."[31]

One of his biographers has listed these factors as the ones that led to his success in roentgenology: "a scientific type of mind developed by a general education, medical and surgical training, special work with the bronchoscope in the removal of foreign bodies, attention to the chest, that one cavity of the body readymade for roentgen examination, skill in photographic methods and dark room technique, and last but not least, a thorough knowledge of pathology, that ultimate foundation of roentgenological interpretation."[7]

It is a great privilege to have been asked to present this Memorial Lecture. The essayist is allowed to bask in the reflected glory of Preston Hickey and to become associated by reputation with all of those distinguished physicians who have preceded him in this task. I am humbly grateful and fully aware of my responsibilities.

Doctor Hickey early became interested in the roentgen examination of the thoracic viscera. One of his early papers, published in 1904, was entitled, "The Interpretation of Radiographs of the Chest."[22] *It is proper, therefore, that this Lecture should be on a subject related to disease of the respiratory system. I have chosen as my title, "Certain Vascular Abnormalities of the Lungs."*

THE presence of anomalous vessels, or abnormalities of vessels normally present in the lung, may cause shadows that

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need explanation on the roentgenograms of a person without clinical symptoms. On the other hand, abnormalities of pulmonary vessels may cause symptoms without producing unusual manifestations on the roentgenographic examinations ordinarily employed. In such cases, more esoteric forms of examination are needed to arrive at a proper diagnosis.

These abnormalities of the blood vessels of the lungs may be divided, for purposes of discussion, into: (1) those of the pulmonary arteries, (2) those of the pulmonary veins, (3) those involving both arteries and veins, and (4) those in which anomalous vessels are present. So few abnormalities of the bronchial arteries have been described that they need not be included in this review.

PULMONARY ARTERIES

The following abnormalities of the pulmonary arteries are among those which have been described: complete absence of one branch, hypoplasia, localized stenosis, aneurysm, diffuse ectasia and aberrance of the left branch. These abnormalities may occur alone or in combination with other lesions of the lungs or heart.

Congenital Absence of One Branch of the Pulmonary Artery. This condition, sometimes called agenesis or aplasia of a pulmonary artery, is one that produces changes in the ordinary posteroanterior roentgenogram of the chest which are sufficiently characteristic to alert the examiner to the presence of this abnormality[15,29,39] (Fig. 1*a*). The lung from which the pulmonary artery is absent is reduced in volume but appears to be normally aerated. Because of this reduced volume, the thorax may be asymmetrical, with the intercostal spaces being narrowed and the volume of the thoracic cavity on this side being reduced. The diaphragm on the affected side is elevated and the mediastinum is shifted toward the abnormal lung. In some cases, there may even be herniation of the normal contralateral lung through the anterior portion of the mediastinum toward the affected side.

Properly exposed roentgenograms will

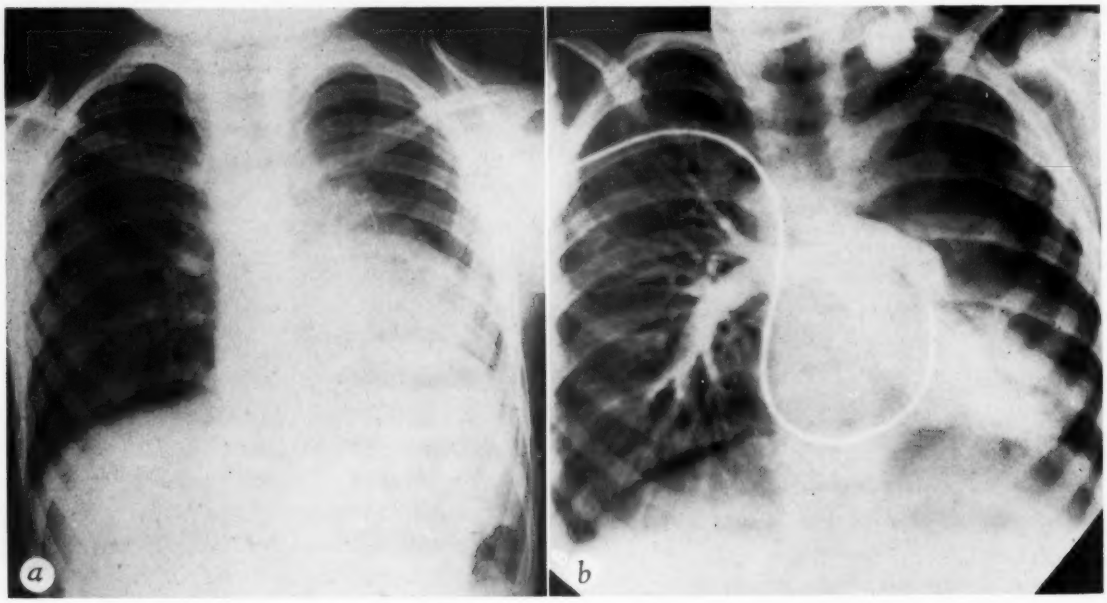

FIG. 1. Congenital absence of the left pulmonary artery. (*a*) Frontal roentgenogram showing the reduced volume of the left lung, the elevated diaphragm and the lack of normal vascular shadows in the left hilus. (*b*) Selective angiocardiogram. Note absence of the left pulmonary artery. Typical tetralogy of Fallot was present in this case in addition to absence of the pulmonary artery. (Reproduced with permission from *J.A.M.A.*, 1960, *173*, 613–624.)

show an absence of the normal vascular shadows at the hilus of the affected lung. In place of the branching system of broad vessels normally seen, there will be a network of much smaller vessels. These are the bronchial arteries, which are the only vessels supplying blood to this lung.

This change in appearance of the hilar vessels is most easily seen when the right pulmonary artery is absent. In cases of agenesis of the left pulmonary artery, the shadow of the left hilus is often obscured by the overlying shadow of the heart, which has shifted to the left.

Patients with absence of one pulmonary artery are often asymptomatic. On the other hand, some cases have been recorded in which hemoptysis was a presenting symptom. It is believed that the increased pressure of the blood flowing through the abnormally large bronchial arteries in the affected lung is responsible for this bleeding, when it occurs. Other symptoms which have been described are dyspnea, cyanosis and cough. Some patients describe repeated attacks of "pneumonia."

The roentgenographic appearance of this condition must be differentiated from other, more common conditions, such as collapse of a lobe or of an entire lung. In such cases, because of bronchial obstruction, the lung is not as well aerated as it is in a case of agenesis of a pulmonary artery. Chronic obliterative pleuritis, such as that which follows empyema or hemothorax, may reduce the volume of a lung. In such a case, there is no obstruction to the airway and the lung appears to be normally aerated. However, the thickness of the fibrotic pleura is usually apparent, which feature serves to distinguish such a condition from absence of a pulmonary artery.

Bronchography in a case of uncomplicated agenesis of the pulmonary artery will show a bronchial tree that is normally developed but crowded together.[37] This serves to distinguish this condition from the more complicated abnormalities of partial or complete agenesis of the lung, in which case the pulmonary artery may also be missing.

Venous or selective angiocardiograms will demonstrate the anatomic features of this condition and will serve to confirm the diagnosis (Fig. 1*b*). No contrast material will be seen to enter the affected lung during the phase of filling of the pulmonary artery, and no vessel corresponding to the pulmonary-artery branch will be apparent. Later roentgenograms will show contrast material entering the abnormal lung through the bronchial arteries during the phase of opacification of the aorta.

Absence of a pulmonary artery may occur as an isolated abnormality, or it may be found in conjunction with other abnormalities of the cardiovascular system. In one of Wyman's[39] cases, there were a right-sided aortic arch, a septal defect in the heart and a patent ductus. In the Mayo Clinic case illustrated in Figure 1, there was a typical tetralogy of Fallot which later was repaired surgically. Vaughan[37] has reported a similar case.

Hypoplasia of a Pulmonary Artery. Maier,[29] Belcher and Pattinson,[2] and Fisher and Van Epps[15] have reported cases of hypoplasia of a major pulmonary artery or one or more of its lobar branches. The roentgenologic appearance in these cases was similar in most instances to that produced by aplasia of a pulmonary artery. However, in most of the cases of hypoplasia, there were associated abnormalities of the bronchial tree and of development of the lung. These cases can be distinguished by careful observation of the bronchograms and angiocardiograms. It is probable that they represent abnormalities in the embryologic development of the lung itself, and not of the pulmonary vessels alone.

Stenosis of a Pulmonary Artery. Single or multiple sites of localized constriction in the pulmonary artery can occur. This condition is sometimes known as coarctation or supravalvular stenosis of the pulmonary artery. Clinically, it is characterized by dyspnea and fatigability and by a systolic murmur best heard in the second and third

intercostal spaces. When associated with other cardiovascular anomalies, cyanosis may be present.

Falkenbach and co-workers[13] have recently presented an excellent review of this condition. They state that the site of stenosis may be in the central portion of the pulmonary artery, in a main branch, or peripheral. If peripheral, there are usually multiple sites of stenosis.

The ordinary roentgenogram of the chest may show no abnormality, or it may present evidence of enlargement of the right ventricle. In some instances, the shadow of the affected pulmonary artery may be relatively inconspicuous while the opposite artery appears enlarged.

The definitive diagnosis can be made only by cardiac catheterization and angiocardiography.

My colleagues and I have observed one case in which the right main pulmonary artery was involved (Fig. 2, *a* and *b*) and one in which there were multiple sites of stenosis in the peripheral pulmonary arterial tree. In the latter case, many of the stenotic arteries showed evidence of poststenotic dilatation.

Enlargement of a Pulmonary Artery. In addition to aplasia, hypoplasia and stenosis, the pulmonary artery may be involved by conditions which cause an increase in its caliber. Most roentgenologists are familiar with poststenotic dilatation of the main pulmonary artery which occurs in cases of pulmonary valvular stenosis. On the roentgenogram, an abnormally large shadow is seen in the vicinity of the hilus of the left lung. Roentgenoscopic observation discloses expansile pulsation of this shadow.

In some instances, poststenotic dilatation of the pulmonary artery may be confused roentgenologically with mediastinal or pulmonary neoplasms. In the absence of conclusive clinical evidence, it may be necessary to employ angiocardiography to make the correct diagnosis.

Aneurysms may occur in a major branch of the pulmonary artery, or in one of the lobar branches. In either instance, the patient may be asymptomatic. My colleagues and I have observed one instance of aneurysm of the right pulmonary artery (Fig. 3, *a* and *b*) in which there was evidence, elicited by laminagraphy, of calcification of the walls of the aneurysm. The patient, a man thirty-seven years of age, had no symptoms referable to the lungs. He had been told that the lymph nodes in the right hilus were enlarged and he had received radiation therapy, with no change in the size of the shadow of the right hilus.

We have also observed an aneurysm of the branch of the pulmonary artery which

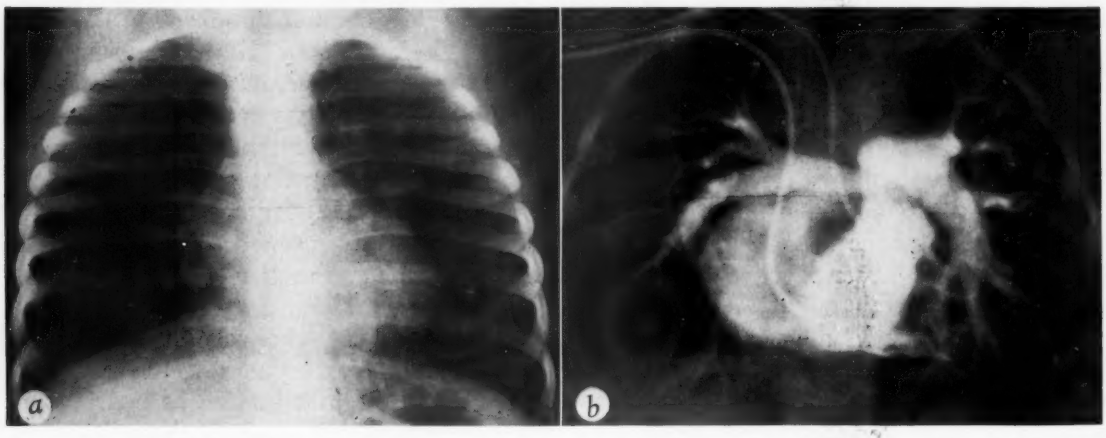

FIG. 2. Stenosis of the right pulmonary artery. (*a*) Routine roentgenogram showing very little evidence of abnormality. The shadows of the vessels in the right hilus are less prominent than those on the left side. (*b*) Angiocardiogram showing that stenosis occurred close to the bifurcation of the main pulmonary artery. There is moderate dilatation of the left pulmonary artery.

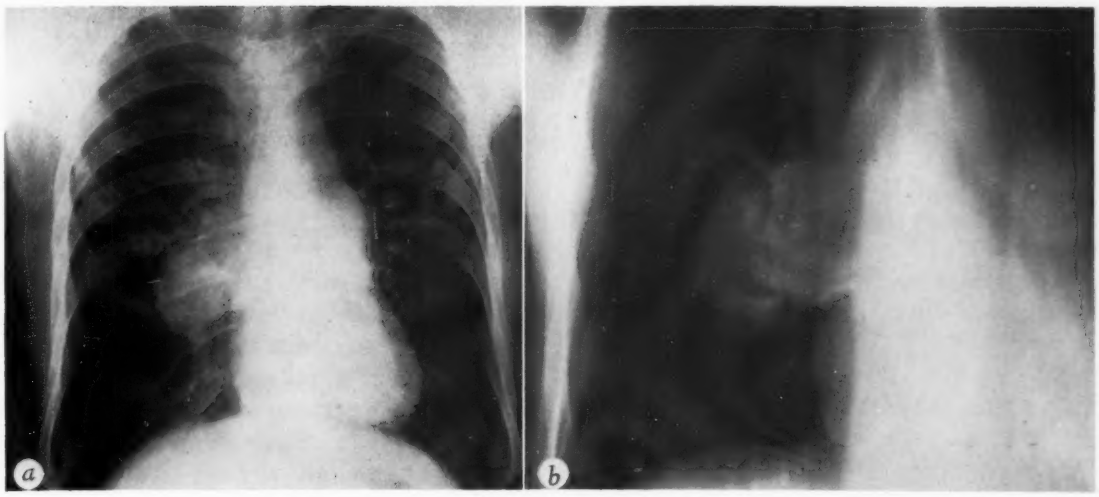

Fig. 3. Aneurysm of the right pulmonary artery. (*a*) Posteroanterior roentgenogram. (*b*) Laminagram showing calcification of the wall of the aneurysm.

supplied the lower lobe of the right lung and which was discovered incidentally during the course of an examination to elicit the cause of headaches. There were no clinical signs of arteriovenous shunt, and after lobectomy the pathologist could find no abnormal communication between the aneurysmal vessel and others, even though the surgeon noted the presence of large branches of the bronchial arteries (Fig. 4).

We have also encountered one case of diffuse aneurysmal dilatation or ectasia of the branch of the left pulmonary artery supplying a portion of the upper lobe of the lung. This case has been reported by MacKenzie and Clagett.[28]

In each of these 3 cases, the aneurysm showed evidence of expansile pulsation at the time of roentgenoscopic examination, and the fact that the lesion was vascular was recognized. A murmur was heard over the aneurysm in each case, but there was no evidence of cyanosis, clubbing of the fingers or other signs of arteriovenous shunt.

Aberrant Left Pulmonary Artery. Late in 1957, Hiller and Maclean[23] reported 3 cases of aberrant left pulmonary artery. They called the condition "pulmonary artery ring" because it resembled, in some respects, the vascular ring formed by the right and left aortic arches when both persist and encircle the trachea and esophagus. By 1959, Rudhe and Zetterqvist[33] were able to collect 11 cases from the literature, and a year later Jacobson and co-workers[25] brought the total up to 15, after adding 3 of their own.

The significant abnormality is one of development of the left pulmonary artery. Instead of branching in normal fashion from the main pulmonary artery and run-

Fig. 4. Aneurysm of the lower lobe branch of the right pulmonary artery.

ning a direct course to the hilus of the left lung, it originates at a point farther to the right, travels in a superior and posterior direction so that it passes above the right main bronchus, and then turns toward the left, passing posterior to the trachea but anterior to the esophagus. From there, it reaches the hilus of the left lung by a direct course.

Patients suffering from this anomaly experience respiratory difficulties in the neonatal period. Stridor is almost always present, and life may be threatened in the more severe cases.

The diagnosis can be made roentgenologically, if the proper examinations are carried out. In some instances, there is emphysema of the right lung because of compression of the right main bronchus by the aberrant artery. In such cases, the mediastinum will be shifted toward the left, especially during expiration.

Examination of the esophagus using an opaque fluid will often disclose a crescentic indentation of its anterior wall at the level of the carina. Roentgenoscopically, this indentation may exhibit pulsation. Several authors have pointed out that this filling defect is seen only if the examination is carried out in the direct lateral position. Laminagrams made in the lateral projection will show posterior narrowing of the trachea at the same level. The aberrant course of the left pulmonary artery can be well demonstrated by angiocardiography.[23,33]

The condition can be corrected surgically if it is recognized. Because of the initial symptom of expiratory stridor, with the subsequent development of dyspnea, cyanosis and bouts of respiratory infection, an aortic vascular ring may be suspected. Patients with this aortic abnormality usually also experience difficulty in swallowing. Such symptoms are not noted by patients with an aberrant left pulmonary artery, for the vessel passes anterior to the esophagus and does not compress it, although it may indent it.

It is likely that more of these cases will be recognized, if the possibility is kept in mind, especially when examining babies suffering from stridor and suspected of having an aortic vascular ring.

PULMONARY VEINS

Normally, there are four pulmonary veins which return the oxygenated blood to the left atrium of the heart. A number of anomalies of these vessels has been identified, most of them concerned with abnormal patterns of communication with the heart. This group of anomalies has been described in the literature under the headings of anomalous venous drainage and anomalous venous connection.

Edwards[11] distinguishes between "drainage" and "connection," saying that "drainage" represents a physiologic phenomenon while "connection" represents an anatomic fact. For example, the pulmonary veins may be connected normally to the left atrium but may empty into the right atrium through a large atrial septal defect situated in the proper position. This would represent abnormal drainage but not an abnormal connection.

Total Anomalous Venous Connection. Anomalous pulmonary venous connection exists in two forms, partial and total. Patients with the total form may be cyanotic. Cooley and Collins[6] list four ways in which all of the blood from the lungs may be abnormally directed to the right atrium. The most common of these anomalies consists of a convergence of the veins from both lungs to form a chamber posterior to the left atrium. However, no opening exists between this chamber and the atrium. A single anomalous vein arises from this chamber and runs superiorly along the left side of the mediastinum to join the left innominate vein. The blood then flows into the right atrium by way of the superior vena cava.

This particular anomaly produces a characteristic pattern on the roentgenogram. It has been called the "figure 8" appearance and is shown in Figure 5. Cooley and Collins list this as the *supracardiac*

form of total anomalous pulmonary venous connection.

These authors also describe a *cardiac* form in which the convergence of the pulmonary veins into a single chamber behind the heart takes place as in the supracardiac form, but this empties directly into the right atrium, or into the right atrium by way of the coronary sinus.

In a third variety, the single anomalous vein that arises from the chamber formed by the confluence of the pulmonary veins extends inferiorly and empties directly or indirectly into the inferior vena cava below the diaphragm. This is known as the *infracardiac* form. In their fourth category are various combinations of these three forms of anomalous connection.

Except for the supracardiac variety, there is no characteristic roentgenologic appearance. However, Cooley and Collins state that in 43 per cent of all cases of total anomalous pulmonary venous connection the anomaly is supracardiac. Therefore, roentgenologists should be expected to recognize almost half of the total number of these venous anomalies.

Partial Anomalous Pulmonary Venous Connection. This causes clinical features that differ from those of the total form. In most instances, the patient is not cyanotic. Dalith and Neufeld[8] state that cyanosis exists only if the recirculation of oxygenated blood exceeds 50 per cent of the total, and then only after the patient has reached adult life.

Many varieties of partial anomalous connection have been described.[8,14,18,36] The veins from the right lung may lead directly into the right atrium, or one or both right veins may empty into the superior vena cava or one of its tributaries, or into the inferior vena cava or one of its tributaries. Veins from the left lung may empty into the left innominate vein or into the superior vena cava on the right side. There may even be an anomalous connection of one left vein to the left innominate and one right vein to the inferior vena cava.

Because many patients with partial anomalous venous connection are asymptomatic, as were 6 of 9 reported by Steinberg,[36] the condition may first be recognized by the roentgenologist as he examines a roentgenogram of the chest made as part of a periodic health examination or for some other purpose. The most frequently encountered abnormality is the shadow of a large vessel running vertically in the right lung. The vessel seems to gather tributaries, grow larger and penetrate the diaphragm near the right cardiophrenic angle. Laminagrams are useful to emphasize the vascular nature of the shadow (Fig. 6, *a* and *b*). Selective angiograms will show the abnormal vascular pattern (Fig. 7, *a*, *b*, and *c*).

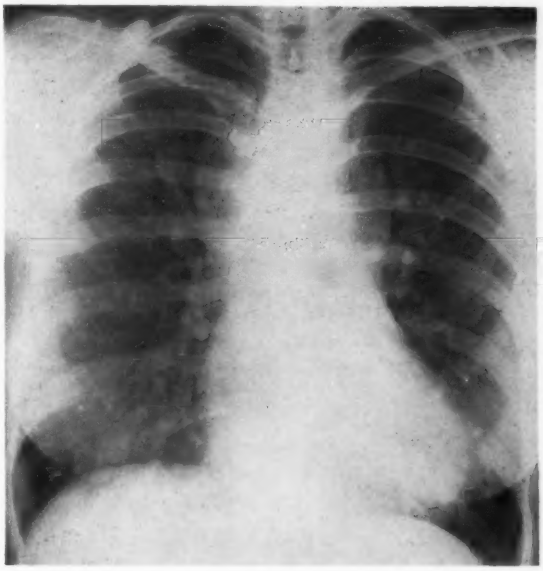

Fig. 5. Total anomalous pulmonary venous connection showing typical "figure 8" appearance. (Reproduced with permission from *J. Thoracic Surg.*, 1956, *32*, 119–134.)

As pointed out by Steinberg, such an anomalous vein may be associated with other anomalies of the lung and its vasculature. There may be hypogenesis of the involved lung with abnormal development of the pulmonary artery and bronchial tree on the same side. My colleagues and I have observed an interesting case in which the right pulmonary artery was absent and the blood supply to the lung was carried by a vessel that arose from the aorta at a point

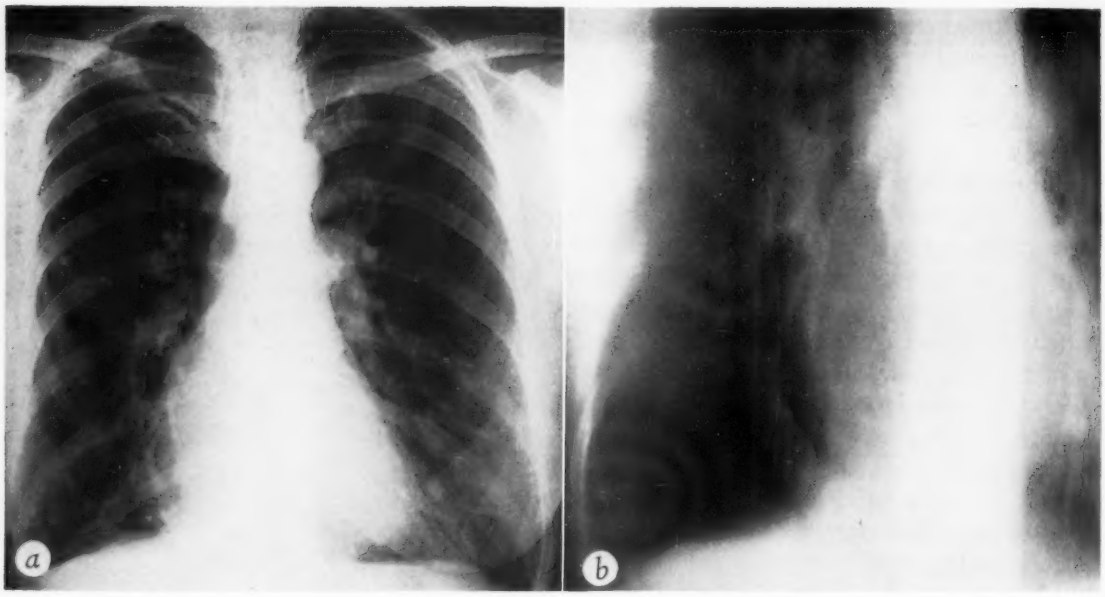

FIG. 6. Partial anomalous pulmonary venous connection on right. (*a*) Posteroanterior roentgenogram. (*b*) Laminagram showing a vein running vertically toward the right cardiophrenic angle. (Reproduced with permission from *J. Thoracic Surg.*, 1956, *32*, 119–134.)

below the diaphragm and entered the hypoplastic lung near the medial basal angle. The anomalous vein retraced this course to enter the inferior vena cava below the diaphragm. Because the right lung was hypoplastic, there were asymmetry of the thorax and dextrorotation of the heart. These latter features together with the vertical vessel could be recognized on the roentgenogram made in the frontal projection, but it was necessary to carry out bronchography and selective angiocardiography before the exact nature of the structural anomaly was known. At first glance, the roentgenogram resembled those seen in agenesis of the right pulmonary artery. A somewhat similar case has been reported by Neill and associates.[30]

Stenosis of a Pulmonary Vein. Stenosis of one or more of the pulmonary veins may occur. This may be a congenital anomaly or an acquired condition. Figure 8*a* shows the appearance in a case of acquired stenosis of the pulmonary veins caused by a granuloma of the mediastinum. It can be noted that the veins draining the lower lobe of the right lung are engorged and that there is evidence of pulmonary edema in this lobe. This is especially pronounced in the region of the right hilus. Catheterization studies demonstrated a marked arterial pulmonary hypertension.

Congenital stenosis of the pulmonary veins has been discussed recently by Edwards.[12] Perhaps the most common site of stenosis on a congenital basis is between the normal left atrium and the abnormal chamber that represents the confluence of the pulmonary veins as seen in cases of so-called cor triatriatum. A similar stenosis may be found between this abnormal chamber and the right atrium in certain cases of anomalous pulmonary venous connection. Figure 8*b* shows the roentgenographic appearance of the lungs of an infant found to have congenital stenosis of the pulmonary veins.[27] The picture is that of diffuse congestion and edema quite similar to that seen in cases of congestive failure.

Enlargement of a Pulmonary Vein. Another interesting abnormality of the pulmonary veins is a localized dilatation of a single vein without accompanying abnormal communication with the arterial

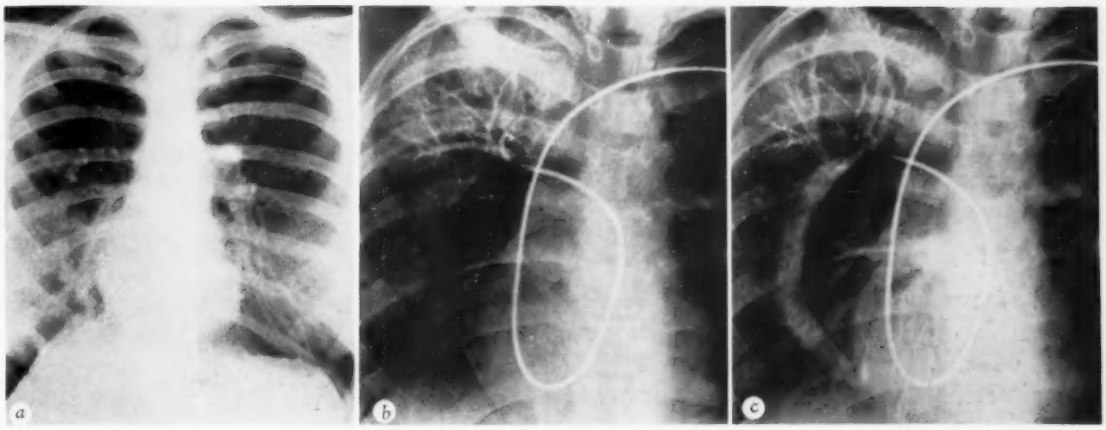

Fig. 7. Partial anomalous pulmonary venous connection on right. (*a*) Posteroanterior roentgenogram. (*b* and *c*) Selective angiograms with injection of contrast material into the upper lobe branch of the right pulmonary artery: (*b*) arterial phase, and (*c*) venous phase, showing an abnormal vein leading toward the right cardiophrenic angle.

supply. Although this might be termed an aneurysm of a pulmonary vein, it is referred to in the literature as a varix.[19,20] In the usual case, an oval shadow is seen on the roentgenogram which has an appearance similar to that caused by certain tumors and arteriovenous fistulas. Laminagrams may disclose that the lesion is part of the vascular system of the lungs, but angiocardiography is necessary to distinguish it from an arteriovenous fistula. It will be found to opacify during the phase of venous filling which is somewhat later than the phase of arterial filling. Roentgenoscopy should reveal a change in size following the Valsalva and Müller maneuvers, but this has not been mentioned in the reported cases. We have observed one

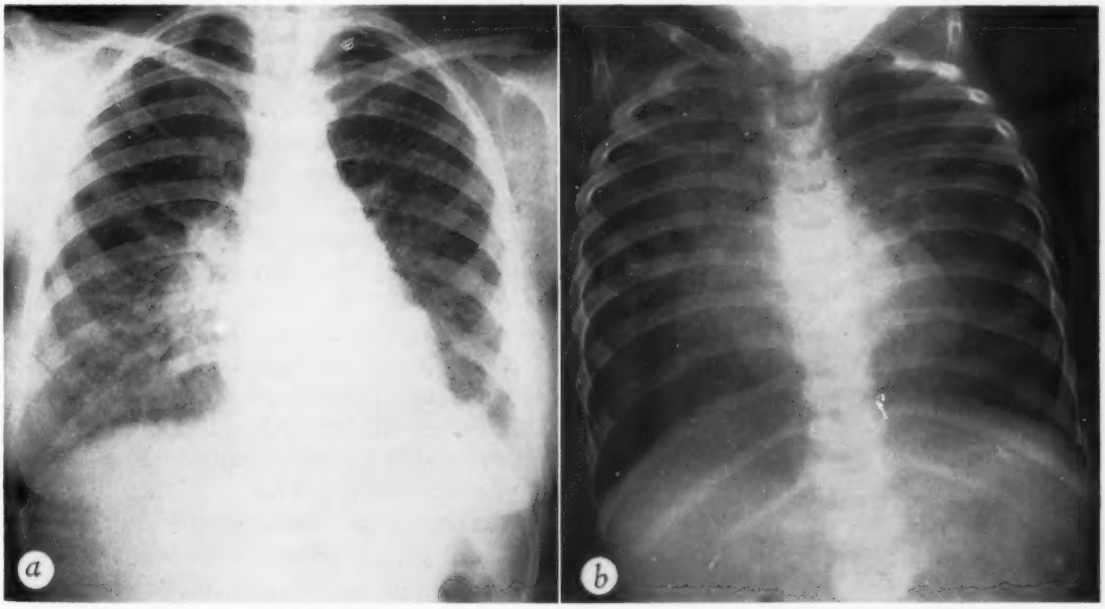

Fig. 8. Stenosis of pulmonary veins. (*a*) Acquired stenosis in an adult caused by granuloma of mediastinum. (*b*) Congenital stenosis in a child. Note evidence of pulmonary edema. (Reproduced with permission from *J.A.M.A.*, 1960, *173*, 637–647.)

case of varix involving the right inferior pulmonary vein (Fig. 9). Surgical exploration was carried out without angiocardiography having been performed or a definitive diagnosis made. As in most of the reported cases, our patient was asymptomatic.

ARTERIES AND VEINS

Arteriovenous Fistula. Pulmonary arteriovenous fistulas are of two types. In one type, which is by far the most common, the abnormal communication is between the pulmonary artery and the pulmonary vein. In this type, the classic clinical triad of cyanosis, polycythemia and clubbing of fingers and toes is found if more than 25 to 30 per cent of the blood in the lesser circulation is being shunted from the right to the left side of the heart through the fistula. This may be the result of one or several large communications or of many small ones.

In the other type, which is rare, the abnormal communication is between the systemic circulation and the pulmonary vessels. In this type, cyanosis and polycythemia do not occur, for the flow of blood, because of the differences in pressures between the two systems, is from the oxygenated systemic circulation to the pulmonary vessels and thence to the left side of the heart.

FIG. 9. Aneurysm or varix of the right inferior pulmonary vein. Note the oval shadow in the right cardiophrenic angle.

Roentgenologic evidence is available in most cases of pulmonary arteriovenous fistula. A few cases have been reported in which multiple tiny fistulas existed but in which no abnormality could be seen on the roentgenogram. Hales[21] has reported 2 cases in which the characteristic triad of clinical signs was present but in which no evidence of the fistulas could be demonstrated even by angiocardiography. The diagnosis was made after death when the lungs were studied by the injection corrosion cast technique. In one case, after the angiocardiographic attempt to corroborate the clinical diagnosis, exploratory thoracotomy with biopsy of the lung also failed to confirm the presence of abnormal arteriovenous communications.

The usual roentgenologic pattern is that of a round or oval shadow in the parenchyma of the lung which appears to be connected to the hilus by two vessels of more than normal size (Fig. 10*a*). Laminagrams are useful in demonstrating these large vessels (Fig. 10, *b* and *c*). Multiple fistulas are present in more than one third of cases.

Although the abnormally large vessels in this condition may look much like those seen in partial anomalous pulmonary venous connection, a distinction can be made. In cases of arteriovenous fistula, two abnormal vessels are visible, the afferent artery and the efferent vein. In cases of partial anomalous venous connection, only one large vein is noted and it receives tributaries which give it a branched appearance.

Roentgenoscopic examination discloses pulsation of the fistula more often than not, and the size of the shadow can be seen to change upon application of the Müller and Valsalva maneuvers.

Frequently, a bruit can be heard in the vicinity of the lesion. If present, it may be-

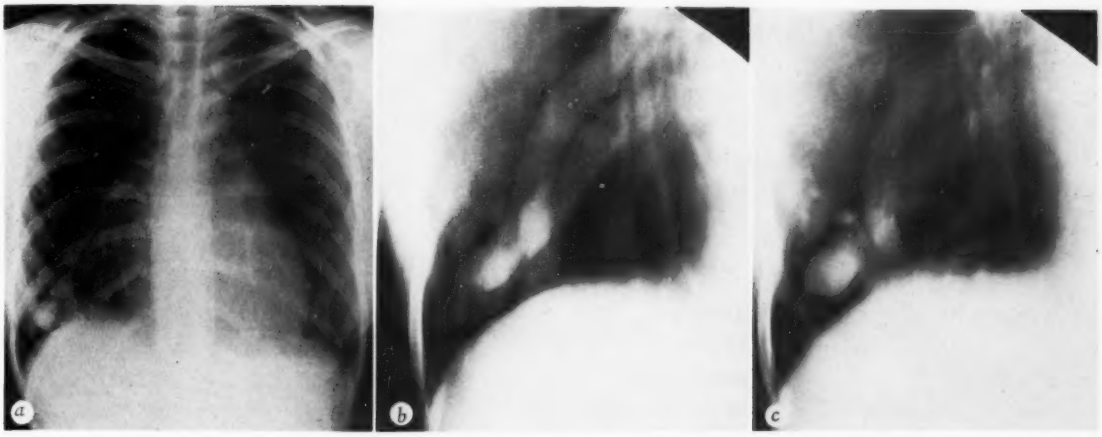

Fig. 10. Arteriovenous fistula in the lower lobe of the right lung. (*a*) Posteroanterior roentgenogram. (*b* and *c*) Laminagrams made at different levels.

come more marked with deep inspiration and diminish with expiration. Steinberg[35] states that the bruit may not be heard over those lesions that are situated deep within the parenchyma of the lung, especially in the medial basal segment of the right lower lobe.

Angiocardiography is the most definitive roentgenologic examination, although rarely, as stated before, it may fail to demonstrate tiny abnormal communications. Serial roentgenograms show the contrast material outlining the enlarged pulmonary artery leading from the hilus to the lesion. The thin-walled aneurysmal sac will then fill, and this will be followed by filling of the enlarged pulmonary vein leading back to the hilus. Sometimes the contrast material will return to outline the left atrium sooner than usual.

We have observed one case, which will be reported in detail elsewhere, in which there was a diffuse arteriovenous malformation in the upper lobes of both lungs. The appearance on the roentgenogram of the thorax made on admission was unusual and it was necessary to inject contrast material directly into the pulmonary artery in order to demonstrate the anatomic abnormality (Fig. 11, *a* and *b*).

Many pulmonary arteriovenous fistulas occur in patients who are suffering from a generalized vascular dysplasia known as hereditary hemorrhagic telangiectasia. The disease consists of the formation in nearly all organs of the body of localized arteriovenous capillary connections which are in reality tiny arteriovenous fistulas. These telangiectatic connections, when they occur in the skin and mucous membranes, form groups of tiny, ruby-colored lesions which blanch when slight pressure is applied over them. They may be recognized easily on the face, on the nasal and buccal mucous membranes, on the lips, and in the nail beds.

The disease is believed to be transmitted by a simple dominant character, and may be carried by both sexes. We have recently reported our observations of a family stemming from a young man who emigrated from Germany to Minnesota approximately 100 years ago.[24] Nearly 40 per cent of 231 individuals about whom we were able to obtain information presented stigmas of the disease. Thirteen of this group were found to have pulmonary arteriovenous fistulas, an incidence of 5.6 per cent of the family group studied, or 14 per cent of the individuals demonstrating telangiectasia. Because of this experience, we believe that all members of families known to have hereditary hemorrhagic telangiectasia should have periodic examinations to search for pulmonary arteriovenous fistulas, whether they have symptoms or not.

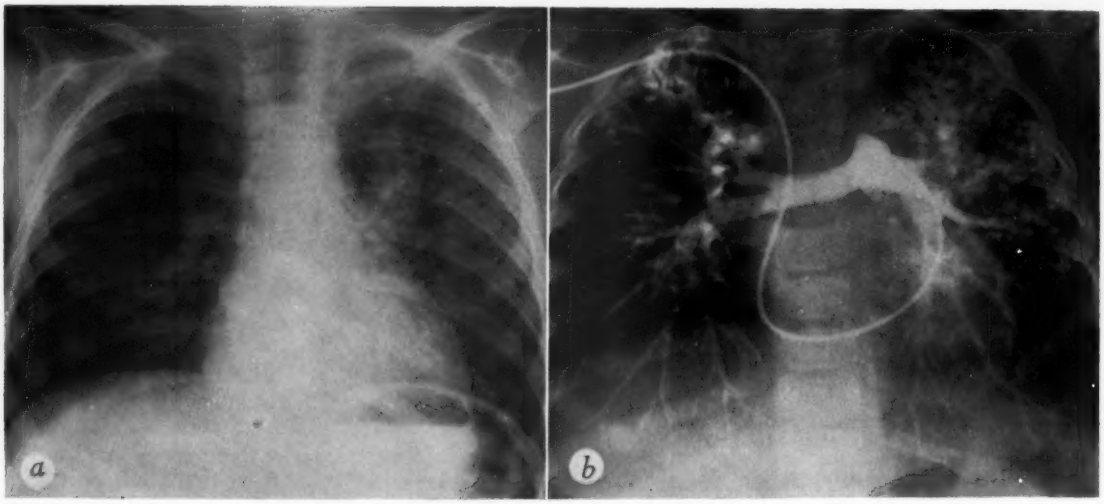

FIG. 11. Diffuse arteriovenous malformation of both upper lobes. (*a*) Routine roentgenogram. (*b*) Selective angiogram.

Systemic-to-pulmonary arterio-arterial or arteriovenous fistulas differ in many respects from the pulmonary-to-pulmonary type which have just been discussed. Patients with these lesions do not exhibit cyanosis because there is no shunt of unoxygenated blood from the right to the left side of the heart. These abnormal communications may occur between the bronchial arteries and the lesser circulation or between the systemic arteries of the chest wall or diaphragm and the pulmonary vessels. In this latter type, there is increased vascularity of the chest wall such as is seen in cases of coarctation of the aorta. Erosions of the inferior surfaces of the ribs, so-called rib notching, were seen in 2 cases observed at the Mayo Clinic (Fig. 12, *a* and *b*). One of these cases has been reported by Burchell and Clagett.[5] Rib notching can also be seen on the reproduction of the roentgenogram of the chest in the case reported by Brain and Kauntze.[3] Davila and associates[9] remarked about the increased vascularity of the chest wall in their report of a case of arterio-arterial fistula which appeared to have followed blastomycosis of the lung.

Venous angiocardiography is frequently not successful in revealing the fistula in cases of systemic-to-pulmonary shunt. This was the experience in the cases reported by Davila and associates and by Brain and Kauntze. In the case reported by Davila and associates, a catheter inserted into the pulmonary artery, followed by rapid injection of contrast material, also failed to show the channels of communication. Brain and Kauntze did notice late opacification of the vessels in the involved portion of the lung at about the time of opacification of the aorta. We have observed this same phenomenon in our most recent case.

Since the direction of flow, because of the differences in pressure between the greater and lesser circulations, is from chest wall to lung, it is probable that thoracic aortography or direct injection of an enlarged intercostal artery would be more helpful in demonstrating the abnormal communications in this type of arteriovenous fistula than is venous angiocardiography.

ANOMALOUS VESSELS

Anomalous vessels communicating with the systemic circulation may be found in association with agenesis or hypogenesis of the lung and in the cases of anomalous pulmonary venous connection. These conditions have already been discussed. The most common pulmonary lesion in which an anomalous artery arises from the greater

circulation is bronchopulmonary sequestration. This condition occurs in two forms, the extralobar, in which a segment of lung tissue is found below the diaphragm or in the thorax but outside the pleural space, and the intralobar form.

Intralobar bronchopulmonary sequestration has been defined as "a congenital pulmonary disease in which a portion of an otherwise normal lobe has no connection with the bronchial tree or pulmonary artery circulation, and receives its arterial supply from anomalous branches of the aorta."[34] In most instances, the anomalous artery arises from the aorta, but it may arise from a branch either above or below the diaphragm.

Many authors have pointed out that the anomalous vessel is elastic in composition rather than muscular,[16,32,34] making it conform to the structure of a pulmonary rather than a systemic artery. For this reason, it is thought that "the primary lesion . . . is some failure of the pulmonary artery in fetal life to supply the segment of lung involved (and) . . . because of this defect the systemic supply to the fetal lung persists."[1]

Patients with bronchopulmonary sequestration may be asymptomatic and the lesion may be discovered incidentally on a roentgenogram made as a part of a periodic health examination. However, in many instances, there is a long history of repeated episodes of pulmonary infection. In some of the reported cases, the lesion was noted on roentgenograms made during the neonatal period.[17,34]

On the roentgenograms, the lesion usually appears as a round, oval or lobulated shadow with its long axis directed medially and posteriorly[40] (Fig. 13, *a* and *b*). In the lateral view of the thorax, the shadow is often less distinct than in the frontal projection.[4] In the majority of instances, the lesion is situated in the position of the posterior basal segment of a lower lobe.

In most cases, the lesion does not communicate with the bronchial tree and, therefore, appears to be solid and homogeneous. Sometimes, however, because of

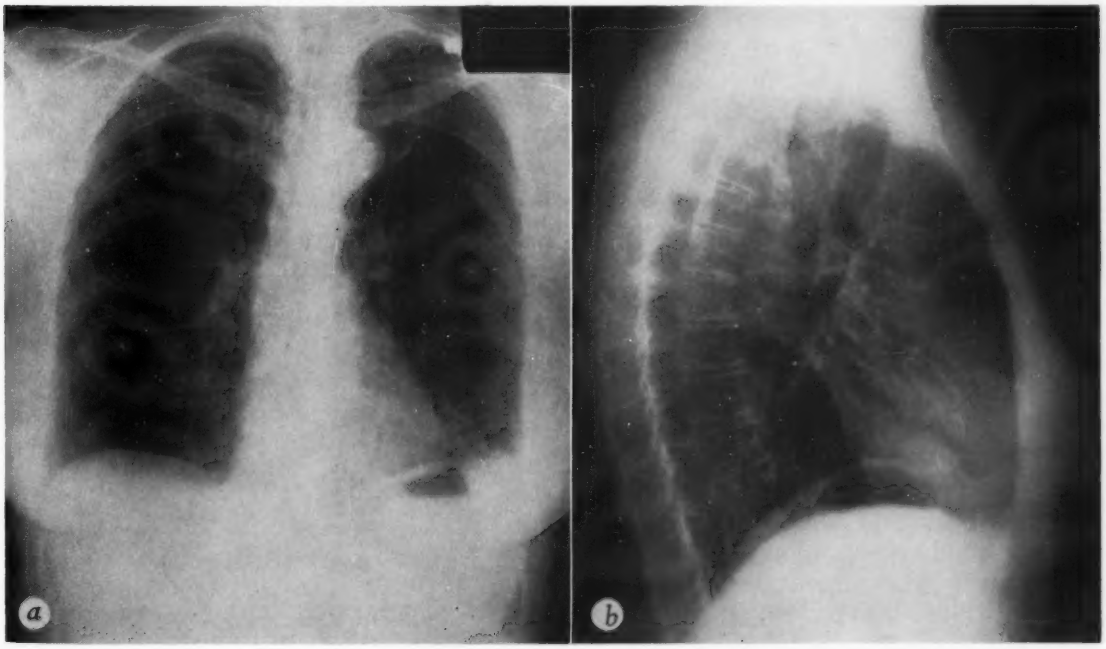

Fig. 12. Arteriovenous fistula in the base of the left lung. The shunt was from the systemic arteries of the thoracic wall to the pulmonary vascular system. (*a*) Posteroanterior roentgenogram. Note the notching of the posterior portions of the ribs on both right and left sides of the body. (*b*) Lateral roentgenogram showing fistula in contact with the diaphragm.

preceding infection, a communication will have opened between the sequestered segment and the bronchial tree, and a fluid level will be noted. In any case, bronchograms seldom demonstrate a channel from the bronchial tree to the abnormal segment, and the usual appearance is one in which the opacified bronchial tree is displaced by the abnormality.

Pathologically, there are several types of intralobar sequestration.[10] In one variety, a single, thin-walled cyst is present. In another, several cysts are gathered together into one conglomerate mass. In a third, there may be no cyst, but a solid mass of unaerated lung through which dilated bronchi run parallel to the anomalous artery. Pigment is usually absent from the sequestered segment, signifying its congenital origin.

The aberrant artery is often as much as 1 cm. in diameter. There may be several anomalous arteries, all arising from the systemic circulation. Laminagrams may demonstrate this abnormal vessel and show that it does not arise in the hilus of the lung as do normal pulmonary arteries (Fig. 14).

Demonstration of the anomalous systemic artery supplying the sequestered segment has been accomplished by means of venous angiocardiography.[17] However, this method is difficult to apply, for the abnormal artery does not fill with contrast material until the aorta becomes opacified. By that time, it may be difficult to distinguish the vessel which has been made visible by very dilute contrast material from the normal pulmonary vessels which are also still faintly visible. A more certain method of demonstrating the aberrant artery is by thoracic aortography.[26,32] In this case, only the anomalous vessel is visualized and there is little danger of being confused by overlying vascular shadows.

While in most of the cases of intralobar bronchopulmonary sequestration the abnormality is situated in the region of the posterior basal segment of a lower lobe, it may be found in other locations. Witten and associates[38] have recently reported 3

FIG. 13. Intralobar bronchopulmonary sequestration of the posterior basal segment of the lower lobe of the left lung. (*a*) On the posteroanterior roentgenogram the lesion is partially obscured by the heart. (*b*) Lateral roentgenogram.

Fig. 14. Laminagram made in the same case as shown in Figure 13. A large artery can be seen running from the mediastinum to the inferior margin of the sequestered segment. At the time of surgical exploration, this was found to arise from the aorta.

cases of sequestration occurring in the upper lobes, with aberrant vessels arising from the right innominate and right subclavian arteries and from the inferior surface of the arch of the aorta.

COMMENT

Certain abnormalities of the pulmonary vessels comprise a group of lesions that may be suspected or recognized because of their roentgenologic appearance. In some instances, the diagnosis can be made only by employing more complicated roentgenologic examinations such as laminagraphy, angiocardiography or thoracic aortography. Surgical treatment is available for some of these conditions. This is especially true of intralobar bronchopulmonary sequestration, arteriovenous fistula and aberrant left pulmonary artery. From the standpoint of the roentgenologist, the most important factor in the diagnosis of these lesions is to keep in mind that such abnormalities occur. Correlation of the roentgenologic appearance with the available clinical information usually leads to the proper diagnosis or to the proper technique for making such a diagnosis. Such correlation of roentgenologic appearance with clinical information was the key to the teaching of Preston Hickey, whose memory we honor tonight.

Mayo Clinic
Rochester, Minnesota

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Vol. 85, No. 6

PULSATIONS IN THE PULMONARY ARTERIES AS OBSERVED WITH ROENTGENOSCOPIC IMAGE AMPLIFICATION

OBSERVATIONS IN PATIENTS HAVING INCREASED PULMONARY BLOOD FLOW

By BRIT B. GAY, Jr., M.D.,* *and* ROBERT H. FRANCH, M.D.†
ATLANTA, GEORGIA

IN PREVIOUS communications, the value of roentgenoscopic image amplification was emphasized as a means of visualizing more adequately the pulsations in the pulmonary arterial tree. Observations were reported in normal subjects[4] and in a group of patients with isolated valvular pulmonic stenosis.[5] A continuation of this study is presented with observations of the pulsations of the pulmonary arteries in a group of patients who were shown by cardiac catheterization to have a left to right shunt with increased pulmonary blood flow and normal or slight elevation of pulmonary artery pressure (26 mm. Hg mean pressure, or less).

METHOD OF STUDY

The patients in this study were examined roentgenoscopically with image amplification, and without prior knowledge of the clinical data or physiologic data obtained by cardiac catheterization. Pulsations were observed in the pulmonary artery segment of the left heart border, the main branch of the left pulmonary artery in the left hilus, the descending branch of the right pulmonary artery in the right hilus, and the basilar division branches of the pulmonary arteries in both lower lobes. Pulsations in the pulmonary arterial branches were graded as absent (0), faintly visible (+), slightly to moderately increased (++), and markedly increased (+++). A roentgenogram of the chest was obtained in posteroanterior projection at 72 inch tube-film distance after the roentgenoscopic examination. From the roentgenoscopic and roentgenographic studies a qualitative prediction was made as to the status of the pulmonary blood flow and pulmonary artery pressure. The roentgenologic studies were then correlated with the physiologic changes present at cardiac catheterization. To date, 280 patients have been studied; of this number 90 patients showed an increase in pulmonary blood flow with a pulmonary artery mean pressure of 26 mm. Hg or less. Atrial septal defect, with or without partial anomalous pulmonary venous drainage, was present in 50 patients including septum primum defects in 5, patent ductus arteriosus in 5, and ventricular septal defects in 35. Tables I and II show the results of the roentgenoscopic findings.

RESULTS

The patients have been divided into two groups:

Group I: *Large Pulmonary Blood Flow.* This includes those patients with a pulmonary blood flow greater than two times the systemic blood flow (pulmonary flow/systemic flow ratio greater than 2.0).

Group II: *Moderately or Slightly Increased Pulmonary Blood Flow.* This includes those patients with a pulmonary blood flow exceeding the systemic blood flow but less than two times the systemic blood flow (pulmonary flow/systemic flow ratio from 1.1 to 1.9).

The mean pulmonary artery pressure in both groups did not exceed 26 mm. Hg.

It will be noted that most patients with

* Associate Professor of Radiology, Emory University School of Medicine, Atlanta, Georgia.
† Assistant Professor of Medicine and Director, Cardiac Catheterization Laboratory, Emory University School of Medicine, Atlanta, Georgia.

TABLE I

GREATLY INCREASED PULMONARY BLOOD FLOW—ROENTGENOSCOPIC FINDINGS

Case No.	Age (yr.)	Sex	Main Pulmonary Artery	Left Pulmonary Artery	Left Basilar Branches	Right Descending Pulmonary Artery	Right Basilar Branches	Mean Pulmonary Artery Pressure (mm. Hg)	Pulmonary/Systemic Flow Ratio
Group 1a—Atrial septal defect, including partial anomalous pulmonary venous drainage and septum primum defects									
1 (D.T.)	2	M	+++	+++	++	+++	++	18	3.2
2 (M.S.W.)	2	F	+++	+++	+++	+++	o	17	3.0
3 (A.C.)	3	F	+++	+++	o	+++	+	22	2.3
4 (M.D.)	6	M	+++	+++	+++	+++	+++	17	3.0
5 (J.B.)	8	M	+++	+++	+++	+++	+++	10	2.1
6 (D.V.)	8	F	+++	+++	++	+++	+	18	2.3
7 (M.V.D.)	9	M	+++	+++	+++	+++	+++	18	2.9
8 (J.L.)	7	F	++	++	++	++	++	19	3.0
9 (D.V.)	9	F	+++	+++	++	+++	++	18	2.3
10 (L.V.)	7	F	+++	+++	+++	+++	+++	17	4.8
11 (P.S.)	11	F	+++	+++	+++	+++	+++	14	3.4
12 (M.A.L.)	11	F	+++	+++	++	+++	++	15	2.4
13 (S.C.)	6	F	++	++	+	+++	+++	18	2.0
14 (E.McE.)	11	F	+++	+++	o	+++	o	22	2.5
15 (K.P.)	7	M	+++	+++	+++	+++	+++	13	3.7
16 (L.S.)	6	F	+++	+++	++	+++	o	21/8	3.1
17 (J.S.)	6	F	++	++	+	+	o	10	3.5
18 (J.H.)	6	F	+++	+++	++	+++	++	28/7	4.5
19 (R.D.)	7	F	++	++	++	+	+	22/7	2.0
20 (J.B.)	9	F	+++	+++	++	+++	++	20	3.3
21 (D.W.)	6	F	+++	+++	+	+++	o	20	2.1
22 (H.P.)	9	M	+++	+++	++	+++	++	13	2.9
23 (J.L.R.)	7	F	+++	+++	++	+++	++	13	3.1
24 (B.S.)	11	F	+++	+++	+	+	o	19	2.5
25 (N.D.)	12	F	+++	+++	+++	+++	+++	16	2.6
26 (S.S.)	17	F	+++	+++	+++	+++	+++	10	2.9
27 (D.T.)	16	F	+++	+++	+++	+++	+++	13	2.6
28 (A.L.)	16	F	+++	+++	++	+++	++	12	3.0
29 (W.E.A.)	13	M	+++	+++	++	+++	++	11	3.2
30 (P.A.R.)	13	F	+++	+++	+++	+++	+++	13	3.0
31 (B.R.)	14	F	+++	+++	+++	+++	+++	14	2.8
32 (K.F.)	33	F	+++	+++	+++	+++	+++	19	3.1
33 (Y.E.)	36	F	+++	+++	+	+++	o	17	2.2
34 (G.H.)	28	F	+++	+++	+++	++	++	14	3.6
35 (J.S.)	19	M	+++	+++	+++	++	++	16	3.2
36 (C.R.)	41	M	+++	+++	+++	+++	+++	16	6.3
37 (N.R.V.)	26	M	+++	+++	+++	++	++	14	2.5
38 (I.L.W.)	39	F	+++	+++	o	+++	+	25	5.1
39 (M.G.)	31	F	+++	+++	+	+++	o	10	2.6
40 (H.W.)	32	F	+++	+++	+	+++	++	15	3.2
41 (P.R.R.)	18	M	+++	+++	+++	+++	+++	12	2.2
42 (B.J.)	46	F	++	++	o	+	o	18	2.9
43 (A.M.)	52	F	+++	+++	++	+++	+	20	3.6
44 (L.F.)	3	F	+++	+++	+++	++	+	12	3.2
45 (S.H.)	4½	F	+++	+++	++	++	+	22	4.6
Group 1b—Ventricular septal defect									
46 (S.C.)	15	F	+++	+++	+++	+++	+++	15	3.0
47 (G.T.)	5	M	+	++	++	++	++	14	2.1
48 (F.C.)	2	M	++	++	++	++	+	22	3.0
Group 1c—Patent ductus arteriosus									
49 (W.T.M.)	10	M	+++	+++	++	+	o	21	2.6

TABLE II

MODERATELY INCREASED PULMONARY BLOOD FLOW—ROENTGENOSCOPIC FINDINGS

Case No.	Age (yr.)	Sex	Main Pulmonary Artery	Left Pulmonary Artery	Left Basilar Branches	Right Descending Pulmonary Artery	Right Basilar Branches	Mean Pulmonary Artery Pressure (mm. Hg)	Pulmonary/ Systemic Flow Ratio
Group IIa—Atrial septal defect, including partial anomalous pulmonary venous drainage and septum primum defects									
50 (T.M.)	4	M	+++	+++	++	++	+	12	1.7
51 (A.C.)	10	F	+	++	+	+	o	11	1.6
52 (C.D.)	17	M	+	+	o	+	o	13	1.4
53 (W.L.P.)	22	M	+++	+++	+++	+++	+++	14	1.8
54 (P.R.)	5	F	+	++	+	+	o	15	1.3
Group IIb—Ventricular septal defect									
55 (C.D.)	1 1/6	F	+	+++	+++	+++	+++	15	1.3
56 (S.C.)	2	F	++	++	+	+	o	8	1.8
57 (J.H.)	2	F	+++	+++	o	o	o	11	1.8
58 (S.P.)	4	M	++	++	++	++	+	19	1.9
59 (C.B.)	4	F	++	++	++	++	++	19	1.5
60 (W.H.)	4	M	++	++	+	+	+	15	1.6
61 (H.M.)	5	M	+++	+++	+++	+++	+++	14	1.2
62 (A.R.)	5	F	+++	+++	+	+	o	15	1.3
63 (A.D.)	4	M	+++	+	+	o	o	12	1.5
64 (A.L.)	4	F	++	++	++	+	o	25	1.6
65 (J.P.)	7	M	+++	+++	+++	+++	+++	19	1.4
66 (J.B.)	10	M	+	++	++	+	+	17	1.5
67 (T.M.)	10	M	+++	+++	++	++	o	9	1.6
68 (B.L.)	7	F	++	++	++	+	o	17	1.3
69 (F.M.)	10	F	+	++	++	+	o	13	1.2
70 (L.McD.)	8	M	++	++	+	++	+	14	1.6
71 (A.M.)	7	F	+++	+++	+++	+++	+++	17	1.9
72 (W.W.)	6	M	+	+	+	+	o	10	1.5
73 (B.C.)	7	F	+	++	o	++	+	25/7	1.6
74 (M.D.)	9	F	++	++	+	+	o	20	1.5
75 (C.S.)	6	F	+++	+++	o	+	o	14	1.4
76 (C.B.)	11	F	+	+++	+	+++	+	18	1.9
77 (E.M.)	7	F	+++	+++	+++	+++	+++	25	1.4
78 (S.P.)	9	F	+++	+++	+	+++	++	25	1.6
79 (R.H.)	12	M	+	+	o	+	o	23/8	1.7
80 (L.C.)	13	M	+++	+++	+++	+++	+	13	1.5
81 (R.D.)	14	F	+++	+++	++	++	+++	12	1.3
82 (W.G.)	16	M	+++	+++	++	+++	+++	19	1.3
83 (O.E.)	12	M	+++	+++	o	+	o	16	1.5
84 (J.H.)	12	F	+++	+++	++	+	o	18	1.3
85 (S.P.)	7	F	+++	+++	+	+	o	20	1.7
86 (R.L.H.)	8	M	+++	+++	++	+	o	11	1.8
Group IIc—Patent ductus arteriosus									
87 (E.T.S.)	6	M	+	+	+	+	o	22/9	1.4
88 (P.W.)	17	F	++	++	+	+	o	10	1.6
89 (R.C.)	16	F	++	++	o	+	o	12	1.9
90 (P.M.)	15	F	+++	+++	+	+	o	15	1.2

an atrial septal defect fell into Group I and most patients with a ventricular septal defect fell into Group II. Group I consisted of 49 patients; Group II of 41 patients.

ANALYSIS OF PULSATIONS WITH LARGE PULMONARY BLOOD FLOW GROUP I (TABLE I)

Pulsations in the left descending pulmonary artery branch in the left hilus were markedly increased (+++) in 42 of 49 patients. In the remaining 7 patients pulsations were graded as ++. The right descending pulmonary branch showed markedly increased pulsations (+++) in 36 patients, moderately increased pulsations (++) in 8 patients, and normal faint pulsations (+) in 5 patients. Pulsations in the pulmonary artery branches at the left base just above the diaphragm were increased (++ or +++) in 38 of the 49 patients. Absent pulsations were recorded in only 4 patients at the left base.

Pulsations were slightly less prominent in the right basilar pulmonary artery branches than at the left lung base (++ or +++ in 31 of 49 patients). Absent pulsations at the right base were recorded in 10 patients.

If the numerical grading of pulsations at each location is averaged for Group I, the following values are obtained (Fig. 1): left descending pulmonary artery branch = 2.8 (normal is 1.5); right descending pulmonary artery branch = 2.6 (normal is 1.0); left basilar pulmonary artery branches = 2.1 (normal is 1.0); and right basilar pulmonary artery branches = 1.7 (normal is 0.1).

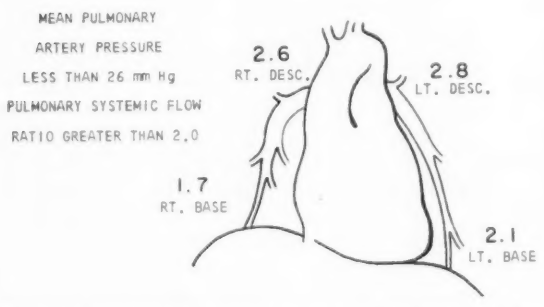

FIG. 1. Average pulmonary artery pulsations with increased pulmonary blood flow in Group I (49 patients).

Of the patients in Group I, only 2 (4 per cent) showed a completely normal pattern of pulsations in the pulmonary arterial tree. The chest roentgenograms in these 2 patients were distinctly abnormal with marked enlargement of the pulmonary arterial and venous trunks.

Pulsations were equal in left and right descending pulmonary artery branches in all except 9 patients.

ANALYSIS OF PULSATIONS WITH MODERATELY TO SLIGHTLY INCREASED PULMONARY BLOOD FLOW GROUP II (TABLE II)

Pulsations in the left descending pulmonary artery branch were graded as +++ in 21 of 41 patients, ++ in 15 patients and +in 5. In the right descending pulmonary artery branch, pulsations were graded as +++ in 10 patients, ++ in 7 patients, + (normal) in 22 patients, and absent (0) in 2 patients. Pulsations at the left base were markedly increased (+++) in 7 patients, slightly increased (++) in 12, normal (+) in 15 and absent (0) in 7. Pulsations in the right basilar pulmonary artery branches were absent (0) in 23 of the 41 patients, normal (+) in 8, slightly increased (++) in 2, and markedly increased (+++) in 8.

It is to be noted that 14 of the 41 patients (34 per cent) showed an entirely normal pattern of pulsation in the pulmonary arterial tree. Also of interest is the fact that, with pulmonary blood flow less than two times the systemic blood flow, pulsations were more asymmetric or unequal between right and left descending pulmonary branches than in those patients having a pulmonary-systemic flow ratio greater than 2.0. Of 41 patients, 23 showed this asymmetry between right and left descending pulmonary artery branches in Group II. The asymmetry was only slight in 15 of the 23 cases, but was rather marked in the remaining 8 cases. In contrast, asymmetry of pulsation between left and right descending pulmonary artery branches in patients of Group I was present

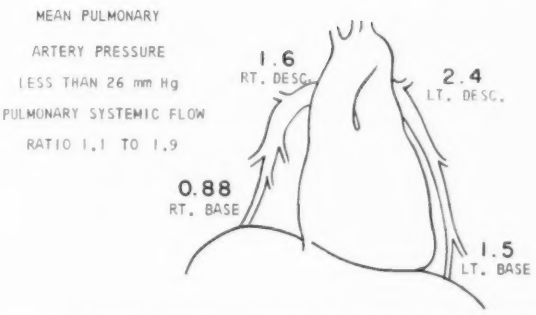

FIG. 2. Average pulmonary artery pulsations with increased pulmonary blood flow in Group II (41 patients).

in only 9 of 49 cases, only 1 of these showing a marked asymmetry.

If numerical grading of pulsations at each location is averaged for Group II, the following values are obtained (Fig. 2): left descending pulmonary artery branch = 2.4; right descending pulmonary artery branch = 1.6; left basilar pulmonary artery branches = 1.5; and right basilar pulmonary artery branches = 0.88.

DISCUSSION

A qualitative evaluation of the pulmonary blood flow is perhaps the most important diagnostic aid that the radiologist contributes in the critical appraisal of a patient with congenital heart disease. Roentgenoscopic study of the pulsations in the pulmonary arterial tree will frequently yield valuable signs of increased pulmonary blood flow which may be inconclusive on routine roentgenograms. The greatest amount of information will be obtained when all roentgenologic studies are evaluated together. Roentgenoscopic and roentgenographic data actually complement each other and neither alone should be relied upon entirely. Conventional roentgenoscopy is unreliable in the evaluation of pulmonary circulatory changes since visual detail is so poor. We believe that the use of image amplification is a necessity if one is to qualitatively evaluate pulmonary blood flow.

Healey *et al.* in 1949[6] were perhaps one of the first group of authors to correlate pulmonary blood flow with pulsations in the pulmonary arteries as seen with conventional roentgenoscopy. They concluded that an increase in pulsation of the pulmonary arteries could be related to an increase in pulmonary blood flow or an increase in pulmonary artery pressure or both. Campbell[3] in 1951 carried out a similar study and came to somewhat different conclusions. He believed that pulmonary artery pulsation was primarily a function of blood flow, whereas dilatation of the pulmonary arteries could result from an increase in pulmonary artery pressure or from an increase in pulmonary blood flow. Abrams[1] presented an excellent study on the roentgenographic differences between increased pulmonary blood flow and pulmonary hypertension. Numerous studies concerning the roentgenologic diagnosis of pulmonary hypertension have been reported,[10] but relatively few articles have appeared on the subject of roentgen diagnosis of increased pulmonary blood flow.

DEFINITION AND ETIOLOGY OF INCREASED PULMONARY BLOOD FLOW

Normally the output of the right ventricle about equals that of the left ventricle. The systemic blood flow in liters per minute will approximately equal the pulmonary blood flow; the ratio of pulmonary blood flow to systemic blood flow normally will be near 1.0. In any situation where a part of the cardiac output from the left side of the heart is shunted away from the systemic circulation into the right side of the heart or into the pulmonary circulation, pulmonary blood flow will exceed the systemic blood flow. The amount of increase in pulmonary blood flow is best expressed as a pulmonary-systemic flow ratio.

An increase in pulmonary blood flow is seen in the congenital left to right shunts (atrial septal defects, ventricular septal defects, patent ductus arteriosus, and atrioventricular cushion defects) and in the complex admixture lesions (truncus arteriosus, single ventricle, transposition of the

great vessels, atrioventricularis communis). The latter lesions are associated with high pulmonary vascular resistance, except when pulmonic stenosis is also present. The former group may have normal or elevated pulmonary vascular resistance. The present report is concerned with those patients who had an increased pulmonary blood flow with normal or low pulmonary vascular resistance and pulmonary artery mean pressure not exceeding 26 mm. Hg.

ROENTGENOGRAPHIC DIAGNOSIS OF INCREASED PULMONARY BLOOD FLOW (TABLES III AND IV)

In small or moderate shunts where the pulmonary blood flow is less than 2.0 times the systemic blood flow, the roentgenographic studies were normal in one third of our patients (Fig. 3, *A*, *B* and *C*). In general, the greater the pulmonary-systemic ratio above this level, the more prominent will be the roentgen changes. The most marked roentgen changes are seen in the patients with atrial septal defects and atrioventricular cushion anomalies, and secondly in those with ventricular septal defects (Fig. 4, *A*, *B* and *C*). For equal amounts of pulmonary blood flow, the patent ductus arteriosus produces the least roentgen change of the pulmonary vascular structures. This fact has been explained[3] by the time difference in the filling of the pulmonary vessels; the septal defects will have only a systolic flow phase, whereas

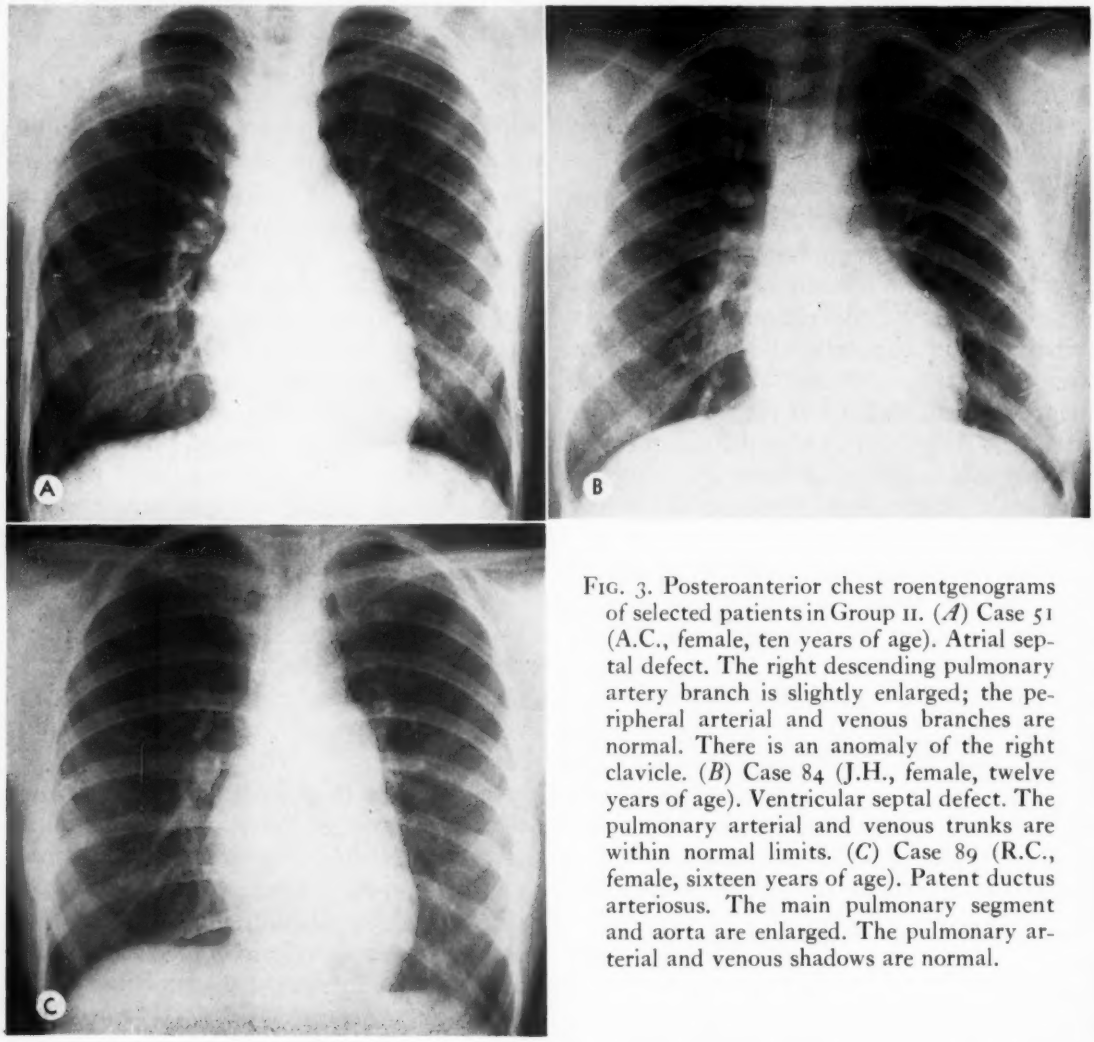

FIG. 3. Posteroanterior chest roentgenograms of selected patients in Group II. (*A*) Case 51 (A.C., female, ten years of age). Atrial septal defect. The right descending pulmonary artery branch is slightly enlarged; the peripheral arterial and venous branches are normal. There is an anomaly of the right clavicle. (*B*) Case 84 (J.H., female, twelve years of age). Ventricular septal defect. The pulmonary arterial and venous trunks are within normal limits. (*C*) Case 89 (R.C., female, sixteen years of age). Patent ductus arteriosus. The main pulmonary segment and aorta are enlarged. The pulmonary arterial and venous shadows are normal.

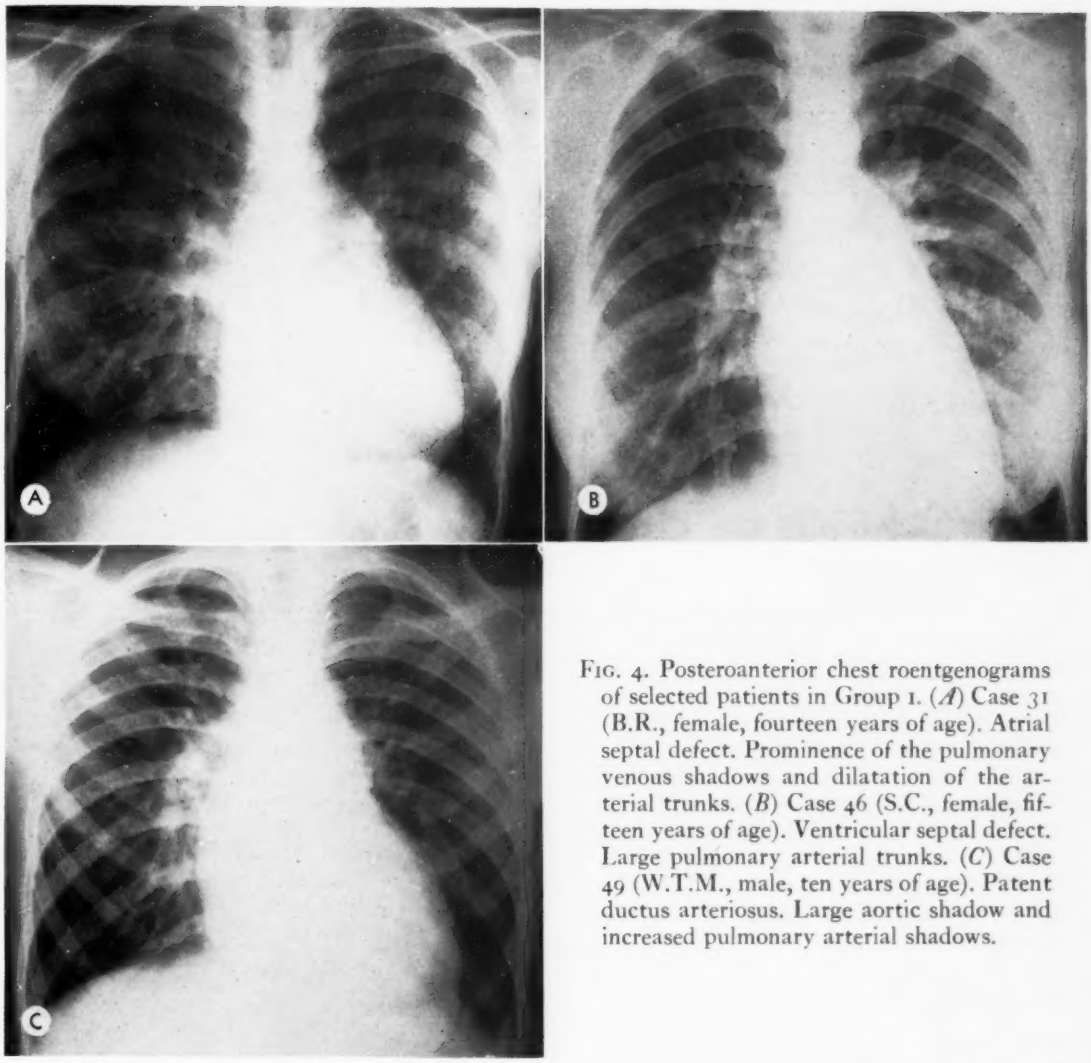

Fig. 4. Posteroanterior chest roentgenograms of selected patients in Group 1. (*A*) Case 31 (B.R., female, fourteen years of age). Atrial septal defect. Prominence of the pulmonary venous shadows and dilatation of the arterial trunks. (*B*) Case 46 (S.C., female, fifteen years of age). Ventricular septal defect. Large pulmonary arterial trunks. (*C*) Case 49 (W.T.M., male, ten years of age). Patent ductus arteriosus. Large aortic shadow and increased pulmonary arterial shadows.

patent ductus arteriosus has a continuous pulmonary blood flow during systole and diastole.

Roentgenographic signs of increased pulmonary blood flow have been described by several authors.[1,7–9] and our studies are in agreement with these (Fig. 3 and 4). The main pulmonary artery segment along the left heart border will show varying degrees of prominence, from a slight convexity to a marked bulge. There is usually dilatation of the right descending pulmonary artery branch in the right hilus (greater than 17 mm. in the adult and adolescent and over 10 mm. in the child). The peripheral arterial branches in the lungs are enlarged so that, as Abrams[1] has shown, the ratio of the size of the central pulmonary branches to the size of the peripheral branches is less than 6:1. The increased vasculature seen in the lung fields is mainly the result of pulmonary venous distention. The dilated superior pulmonary veins produce the prominence of the upper hilar shadow in the frontal roentgenogram. The large inferior pulmonary veins are seen as horizontal vascular shadows below the hilar area, particularly along the right lower heart border. The inferior pulmonary veins on the left side are partially obscured by the heart, but can be well demonstrated by laminagraphy. This technique is also helpful in separating the pulmonary arterial and venous shadows and a study of many

TABLE III

GREATLY INCREASED PULMONARY BLOOD FLOW—ROENTGENOGRAPHIC FINDINGS

Case No.	Age (yr.)	Sex	Heart Size (cardio-thoracic ratio)	Main Pulmo-nary Artery	Left Pulmo-nary Artery	Left Basilar Branches	Right Descend-ing Pul-monary Artery	Right Basilar Branches	Aorta	Pulmo-nary Veins
Group 1a—Atrial septal defect, including partial anomalous pulmonary venous drainage and septum primum defects										
1 (D.T.)	2	M	53.6	++	++	++	12	++	o	++
2 (M.S.W.)	2	F	60.5	++	++	+	11	+	o	++
3 (A.C.)	3	F	54.2	+++	+++	+	8	+	o	+++
4 (M.D.)	6	M	58.8	++	+++	++	14	++	o	+++
5 (J.B.)	8	M	45.5	++	++	+	12	+	o	++
6 (D.V.)	8	F	58.0	+++	++	++	13	++	o	++
7 (M.V.D.)	9	M	49.6	++	+++	+++	17	+++	o	+++
8 (J.L.)	7	F	55.6	+	+	++	12	++	+	++
9 (D.V.)	9	F	48.8	+++	++	++	12	++	o	++
10 (L.V.)	7	F	49.2	++	++	++	13	++	o	++
11 (P.S.)	11	F	53.3	++	++	+	12	+	o	++
12 (M.A.L.)	11	F	48.5	+	+++	+++	15	+++	o	+++
13 (S.C.)	6	F	49.5	++	+	+	12	+	o	+
14 (E.McE.)	11	F	44.2	+++	+++	+	14	+	o	++
15 (K.P.)	7	M	52.3	++	++	+	14	+	o	+++
16 (L.S.)	6	F	46.2	+++	++	+	14	+	+	++
17 (J.S.)	6	F	50.3	++	++	++	12	+	o	++
18 (J.H.)	6	F	52.4	++	++	++	13	++	o	+++
19 (R.D.)	7	F	47.7	+	++	+	12	+	++	+++
20 (J.B.)	9	F	66.5	+++	+	+	14	+	o	++
21 (D.W.)	6	F	57.5	+++	++	++	15	++	o	+++
22 (H.P.)	9	M	47.0	+++	++	++	15	++	o	+++
23 (J.L.R.)	7	F	54.6	++	++	+	11	+	o	++
24 (B.S.)	11	F	50.7	++	++	+	15	+	o	+++
25 (N.D.)	12	F	46.0	++	+++	++	15	++	o	+++
26 (S.S.)	17	F	45.5	++	++	++	17	++	+	+++
27 (D.T.)	16	F	55.5	++	+++	+	18	+	o	++
28 (A.L.)	16	F	48.2	+++	+++	++	15	++	o	+++
29 (W.E.A.)	13	M	49.6	+	++	++	18	++	o	+++
30 (P.A.R.)	13	F	47.4	+++	+	+	15	+	o	++
31 (B.R.)	14	F	51.7	++	+++	++	13	++	o	+++
32 (K.F.)	33	F	53.0	++	+++	++	18	++	o	++
33 (Y.E.)	36	F	59.0	+++	++	+	16	+	o	+++
34 (G.H.)	28	F	49.4	+	++	+	16	+	+	++
35 (J.S.)	19	M	43.2	+	+	++	12	++	o	+++
36 (C.R.)	41	M	53.2	++	+++	++	23	++	++	+++
37 (N.R.V.)	26	M	49.7	+	+	+	16	+	+	++
38 (I.L.W.)	39	F	58.7	+++	+++	+	—	+	+	++
39 (M.G.)	31	F	48.2	+	+++	++	21	++	+	+++
40 (H.W.)	32	F	49.7	++	+++	+	20	++	o	+++
41 (P.R.R.)	18	M	44.8	+++	++	++	18	++	+	++
42 (B.J.)	46	F	60.5	+++	+++	++	18	++	o	+++
43 (A.M.)	52	F	65.0	+++	+++	+++	22	+++	+	+++
44 (L.F.)	3	F	52.4	+++	++	+	7	+++	+	+++
45 (S.H.)	4½	F	60.6	+++	+++	+++	10	+++	o	+++
Group 1b—Ventricular septal defect										
46 (S.C.)	15	F	52.6	+++	+++	+++	19	+++	o	+++
47 (G.T.)	5	M	45.8	++	+	+	10	+	o	++
48 (F.C.)	2	M	49.2	+	+	+	12	+	++	++
Group 1c—Patent ductus arteriosus										
49 (W.T.M.)	10	M	55.4	+++	+	+	13	+	+++	++

TABLE IV

MODERATELY INCREASED PULMONARY BLOOD FLOW—ROENTGENOGRAPHIC FINDINGS

Case No.	Age (yr.)	Sex	Heart Size (cardio-thoracic ratio)	Main Pulmonary Artery	Left Pulmonary Artery	Left Basilar Branches	Right Descending Pulmonary Artery	Right Basilar Branches	Aorta	Pulmonary Veins
Group IIa—Atrial septal defect, including partial anomalous pulmonary venous drainage and septum primum defects										
50 (T.M.)	4	M	51.6	++	+++	+++	12	+++	o	+++
51 (A.C.)	10	F	47.2	++	+	+	14	+	o	++
52 (C.D.)	17	M	44.4	+	++	+	16	+	o	++
53 (W.L.P.)	22	M	41.1	+	++	+	18	++	+	++
54 (P.R.)	5	F	45.0	+	++	+	9	+	o	+
Group IIb—Ventricular septal defect										
55 (C.D.)	1⅙	F	60.6	+++	++	+	9	+	o	+
56 (S.C.)	2	F	49.7	+	+	+	9	+	+	+
57 (J.H.)	2	F	55.3	+	+	+	9	+	+	+
58 (S.P.)	4	M	50.6	++	++	+	10	+	o	++
59 (C.B.)	4	F	57.6	++	++	+	11	+	+	++
60 (W.H.)	4	M	48.4	+	++	+	15	+	+	+
61 (H.M.)	5	M	50.6	+	+	+	10	+	o	++
62 (A.R.)	5	F	41.4	+	++	+	11	+	o	+
63 (A.D.)	4	M	60.7	+++	+	+	9	+	right arch	+
64 (A.L.)	4	F	57.5	+	+	+	7	+	o	+
65 (J.P.)	7	M	57.6	+	++	+	13	+	+	++
66 (J.B.)	10	M	53.8	++	++	+	11	+	+	+
67 (T.M.)	10	M	50.0	+	++	+	15	+	o	++
68 (B.L.)	7	F	43.3	++	+	+	12	+	+	++
69 (F.M.)	10	F	42.9	+	++	+	12	+	+	++
70 (L.McD.)	8	M	41.0	++	++	+	13	+	o	+++
71 (A.M.)	7	F	45.8	++	++	+	15	+	+	++
72 (W.W.)	6	M	46.3	+	+	+	13	+	o	++
73 (B.C.)	7	F	45.0	++	++	+	14	+	+	+
74 (M.D.)	9	F	40.4	++	+	+	13	+	o	+
75 (C.S.)	6	F	46.4	++	+	+	12	+	++	++
76 (C.B.)	11	F	53.2	+	++	+	12	+	o	++
77 (E.M.)	7	F	63.6	+	+	+	15	+	o	++
78 (S.P.)	9	F	52.8	+	+	+	12	+	+	+
79 (R.H.)	12	M	46.0	+	+	+	11	+	o	+
80 (L.C.)	13	M	43.5	++	++	+	13	+	+	++
81 (R.D.)	14	F	44.3	++	++	+	13	+	+	+
82 (W.G.)	16	M	44.8	++	++	+	16	+	+++	+++
83 (O.E.)	12	M	50.0	+	+	+	11	+	+	+
84 (J.H.)	12	F	45.0	+	++	+	13	+	+	+
85 (S.P.)	7	F	51.2	++	+	+	13	+	o	+
86 (R.L.H.)	8	M	38.1	+	+	+	12	+	+	+
Group IIc—Patent ductus arteriosus										
87 (E.T.S.)	6	M	42.1	++	+	+	12	+	+	+
88 (P.W.)	17	F	40.6	++	+	+	10	+	+++	+
89 (R.C.)	16	F	47.2	+++	++	+	11	+	+++	++
90 (P.M.)	15	F	47.0	+	+	+	12	+	+	+

serial laminagrams of the chest has made evaluation of the routine chest roentgenogram more accurate in the recognition of the type of vascular shadow.

ROENTGENOSCOPY WITH IMAGE AMPLIFICATION

Roentgenoscopy with image amplification will show a pronounced increase in the pulsatile activity of the main pulmonary segment along the left heart border, in the left pulmonary artery branch in the left hilus, in the right descending pulmonary artery branch in the right hilus, and in the basilar branches of both lower lobes when the pulmonary blood flow is more than two times the systemic blood flow. As noted in Table I, atrial septal defect and the atrioventricular cushion anomalies will show the most marked pulsations. These lesions usually exhibited the highest pulmonary-systemic flow ratios. Ventricular septal defects showed more variation in pulsations than did the atrial septal defects, but, in general, the pulmonary flows were somewhat less in magnitude. Our experience with patent ductus arteriosus is limited, but a slightly different pulsatile pattern was observed in this group (only 5 cases). Moderate to marked increase in pulsations in the main and left pulmonary artery branches was seen, whereas only faint pulsations in the right descending pulmonary artery branch and no pulsations in the right basilar branches were noted. This pattern of pulsations simulates that seen in pulmonary valvular stenosis, but differs from the latter by having marked, associated aortic pulsations.

FACTORS IN THE PRODUCTION OF VISIBLE PULSATIONS IN THE PULMONARY ARTERIES

The visible intrinsic pulsation in the pulmonary artery in patients with normal pulmonary artery blood pressure and increased pulmonary blood flow is most likely related to the right ventricular stroke volume. With the increase in ventricular stroke volume, there is also an increase in the speed of ventricular ejection. Our atrial septal defect group has the highest right ventricular stroke volume and shows the widest intrinsic pulmonary artery pulsations.

In atrial septal defect, the shunted blood fills the right ventricle in diastole via the tricuspid valve; in ventricular septal defect, shunted blood fills the right ventricle predominantly in systole; in patent ductus arteriosus, direct pulmonary artery filling occurs in both systole and diastole. Whether or not the way in which filling occurs influences intrinsic pulmonary artery pulsations cannot be determined from this study because of the large differences in pulmonary blood flow depending on the anatomical defect present.

In untrained subjects following vigorous exercise, no significant increase in pulmonary artery pulsations occurred.[4] One may speculate that in these cases the increase in cardiac output was predominantly due to an increase in heart rate rather than in stroke volume. When there is much pulmonary regurgitation, as may occur after surgery on a stenotic pulmonary valve, intrinsic pulmonary artery pulsations are increased presumably because of increased right ventricular stroke volume.

The physical properties of the large elastic pulmonary arteries are probably similar within each defect group; anatomic changes in the vessel walls are of little importance in the production of abnormal pulsations. The correlation of pulmonary artery pulse pressure with visible pulsation awaits a faithful recording of pulmonary artery pressure via a catheter tip transducer.

CHANGE IN PULMONARY ARTERY PULSATIONS AFTER OPERATIVE REPAIR OF DEFECT

Nine of our patients (all in Group I), as well as 4 additional patients for whom no preoperative studies were available, have been studied postoperatively after repair of the underlying defect (Table V). It will be noted that a striking change occurs in pulsations in right pulmonary artery branches; in all cases except I, the right descending pulmonary artery branch was graded as + (normal). Also, no pulsations

TABLE V

INCREASED PULMONARY BLOOD FLOW—ROENTGENOSCOPIC FINDINGS AFTER OPERATIVE REPAIR OR DEFECT

Case No.	Main Pulmonary Artery	Left Pulmonary Artery	Left Basilar Branches	Right Descending Pulmonary Artery	Right Basilar Branches
4 (M.D.)	+++	++	+	+	o
7 (D.V.)	+++	+++	+++	+	o
9 (D.V.)	+++	+++	+	+	o
10 (L.V.)	+++	+++	o	+	o
25 (N.D.)	+++	+++	+	+	o
33 (Y.E.)	+++	+++	+	+	o
34 (G.H.)	+++	+++	+	+	o
36 (C.R.)	++	++	o	++	o
41 (P.R.)	+++	+++	+	+	o
(S.G.)*	+++	+++	++	+	o
(P.L.)*	+	+	o	+	o
(M.F.)*	++	+	+	+	o
(D.M.)*	+++	++	o	+	o

* Not seen preoperatively.

were observed in the basilar pulmonary artery branches in the right lung (a normal finding). The left pulmonary artery and its basilar branches, in contrast, showed little change when compared with the preoperative study (Table III). Roentgenographically, the pulmonary artery shadows showed some regression in size, but not nearly as much as did the pulmonary veins, which returned to a normal state in the postoperative study (Fig. 5, *A* and *B*). It is, thus, the pulmonary veins which contribute most prominently to the "increased vascularity pattern" seen roentgenographically in patients with increased pulmonary blood flow.

From this limited number of observations, it is suggested that, if a patient with

FIG. 5. (*A*) Preoperative and (*B*) postoperative posteroanterior roentgenograms of the chest. Case 43 (A.M., female, fifty-two years of age). Atrial septal defect. Note diminution in size of the pulmonary veins after repair of the atrial septal defect with persistent enlargement of the central pulmonary arterial trunks.

a septal defect continues to show abnormally increased pulsations in the right pulmonary artery branches after surgical repair, one should be very suspicious that the repair has been incomplete and that a residual left to right shunt is present.

SUMMARY

Pulmonary blood flow exceeds systemic blood flow in the presence of a left to right shunt. Increased pulmonary blood flow is manifested by an increased pulsation of the main, left and right and basilar pulmonary artery branches in the lungs as observed with roentgenoscopic image amplification. Roentgenographically, there is dilatation of the main, hilar and peripheral pulmonary artery branches. The pulmonary venous shadows are particularly increased and contribute considerably to the "increased vascular pattern" seen roentgenographically. The aorta shows increased pulsations if the left to right shunt is due to an aortopulmonary communication. Roentgenoscopy with image amplification may provide evidence of increased pulmonary blood flow even though the roentgenographic findings are equivocal. Roentgenoscopy with image amplification is an essential part of the evaluation of a patient under clinical investigation for cardiac disease both pre- and postoperatively.

Brit. B. Gay, Jr., M.D.
Emory University Clinic
Department of Radiology
P.O. Box 459
Atlanta 22, Georgia

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ARTERIOGRAPHIC CATHETERIZATION TECHNIQUES*

By ERIK BOIJSEN, M.D., *and* GEORGE L. FEINSTEIN, M.D.†
LUND, SWEDEN

ANGIOGRAPHIC procedures are increasing in number and importance in the investigation of the various vascular systems. A thorough knowledge of the techniques is necessary to achieve good diagnostic studies with minimal risk. This report presents a comprehensive discussion of percutaneous arteriographic catheterization techniques and complications that may occur. The discussion is based on a series of angiographic studies performed in the Roentgen-Diagnostic Department of the University Hospital, Lund, Sweden.

REVIEW OF METHODS

Two methods have been developed for angiographic studies. The first is by means of direct needle puncture and the second by catheterization.

DIRECT NEEDLE PUNCTURE TECHNIQUE

The first practical method of arteriography was by means of puncturing the vessel (by direct exposure or percutaneously) and injecting contrast media. This was the first method used to demonstrate vessels of the extremities,[7] brain,[58] aorta[21] and the left heart chamber.[61]

CATHETERIZATION TECHNIQUES

A further important contribution to the study of the vascular system was achieved by the introduction of a catheter for the injection of the contrast medium.[30,59,81] This permitted a more selective demonstration of predetermined regions.

Insertion of the Catheter. The first practical technique of arterial catheterization in man was reported in 1938 by Ichikawa[42] and in 1941 by Fariñas.[29] The femoral artery was exposed and a ureteral catheter was passed into the aorta. In 1947, Radner,[74] of this department, passed a catheter from the radial into the vertebral artery. This was the first time selective arterial catheterization had been performed.

The method of catheterization via the radial artery was soon used to investigate the subclavian, thoracic and coronary arteries as well as the vertebral.[12,47–49,75–78] The Radner technique was used in this department to investigate the abdominal aorta and its branches during the years 1947–1953. In other centers, direct needle puncture of the aorta was the prevalent method.

A further advance was made in 1951 when Peirce[71] reported a percutaneous method of arterial catheterization. He introduced a polyethylene catheter through a puncture needle into the arterial lumen. Seldinger[82] improved upon this technique by first introducing a guide wire through the needle into the lumen of the artery. The needle was removed and a polyethylene catheter was threaded over the guide into the artery. The guide was then removed leaving the catheter in place. By this latter method a catheter was exchanged for a puncture needle, both with the same outer diameter. This prevented excess trauma to the arterial wall as well as hematoma formation.

Types of Catheters. Ureteral catheters were the first types used. In 1941, Cournand and Ranges[18] described a radiopaque catheter that is still used, especially for angiocardiography. Rodriguez-Alvarez and Martinez de Rodriguez[80] carried out a comprehensive study of the flow rates of different types of catheters with different injection pressures. They stressed the importance of side holes near the tip of the cath-

* From the Department of Diagnostic Radiology, University of Lund, Sweden.
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† Present address: Department of Radiology, Presbyterian Medical Center, San Francisco, California.

eter to decrease recoil and increase the amount of contrast medium per unit time. These catheters, which are occluded at the end, are introduced through a peripheral artery and are used for angiocardiography, left heart ventriculography and aortography.

The polyethylene catheter[46] was first used by Helmsworth *et al.*[41] for arteriography. This type of catheter is a necessary part of the armamentarium for the percutaneous technique of catheter introduction because it is flexible, thin-walled and has an outer diameter the same size as or smaller than the puncture needle. The catheter can also be easily preshaped for the selective study of any vessel or region.

The Radner technique could be used to obtain selective studies of the subclavian and vertebral arteries as well as the left ventricle of the heart. However, with the increasing demand for selective studies of other branches of the aorta, Tillander,[85] also of this department, in 1951 designed a catheter with a metal tip which could be directed by an electromagnetic field. In the same year, Bierman *et al.*[9] made selective studies of the abdominal vessels by means of a radiopaque catheter introduced through the exposed carotid, brachial and femoral arteries.

One of the disadvantages of the polyethylene catheter was the lack of radiopacity, particularly during fluoroscopy. Gidlund[32] overcame this by using a catheter with a metal tip. Edholm and Seldinger[23] left the guide wire in place during fluoroscopy. Lindell and Olin[53] applied a heavy metal to the tip of the guide. Gollmann[34–36] used a straight polyethylene catheter and then substituted the straight inner part of the guide for one with a fixed curve at the tip once the catheter was in the aorta. Ödman[62–68] incorporated lead oxide into the polyethylene catheter, thus making it radiopaque. Although the outer diameter of this catheter was larger than that of a nonopaque polyethylene catheter having the same lumen, the tip could be tapered so that it was easy to introduce by the Seldinger technique.

Certain precautions were proposed for arteriographic catheterization in order to obtain optimal results with minimal complications. The catheter should be tapered at one end for ease of introduction and reduction of trauma to the artery wall.[64,83,91] Side holes should be punched obliquely to the long axis near the tip of the catheter in order to reduce recoil during the injection phase.[32,64,80]

Ödman[68] showed that all catheters, except those which he designed, gradually tend to straighten out and so lose their preformed shape. The lead oxide in his catheters changed the physical properties of the polyethylene so that it would maintain its shape at body temperature.

Additional Technical Aids. Many methods have been used to enhance diagnostic potentialities of the catheterization method. A temporary slowing of the blood flow during the injection phase has been proposed: (1) by lowering the blood pressure; (2) by raising the intrabronchial pressure; (3) by decreasing the heart rate with acetylcholin or prostigmin; and (4) by introducing balloon catheters into the aorta or caval veins.[5,10,22,50,54,60]

Olin[69] preformed a yellow radiopaque catheter as if for left heart ventriculography but shaped the distal part into a loop with its plane running at right angles to the long axis of the catheter. This gave excellent results in dog experiments using small amounts of contrast material[6] but has not been fully developed for use in humans, as there is a risk of coagulum formation.[91]

Full control of the injection rate is necessary for an optimal study. Automatic injection machines have been invented to decrease the radiation hazard to the radiologist as well as to provide a consistent and controlled injection.[32,33,54,80]

The development of the automatic film changer[32] has augmented the usefulness of selective arteriographic studies.

COMPLICATIONS

Complications have been noted both at the puncture site, during introduction of the catheter, and within the vessels, caused by the catheters or guide wires and by the various contrast media used.

Complications at the Site of Catheter Introduction. Bleeding, thrombosis and embolism have been reported with the direct exposure method of catheterization.[9,71] There is also a greater chance of infection by this method.[37]

Ödman[65] reported a few cases of thrombosis of the femoral vein and a slight postangiographic fever with the percutaneous method. This was probably due to the high percentage of hematoma formation at the puncture site caused by using the large bore radiopaque catheter (2.85 mm. outside diameter). To reduce the risk of hematoma formation, compression over the puncture site was recommended for ten to fifteen minutes by hand or by a special compression apparatus[33] at the completion of the study. Once a hematoma had developed, an injection of permease was recommended[86] with compression over the puncture site for a half hour to aid resorption. Aldman[2] suggested rubbing ointment of hirudoid on the skin over the puncture site to prevent thrombophlebitis and help resorption.

Peirce and Ramey[72] reported a case of arteriovenous fistula between the femoral artery and saphenous vein following percutaneous puncture.

Complications Caused by the Guide Wire or Catheter. The tip of the guide wire may not pass the bifurcation of the aorta in cases with marked tortuosity. If the guide wire or catheter is forced against resistance, the tip of the guide may break or the catheter may perforate the aortic wall.[37,86]

Only a few reports of coagulum formation in the catheter have appeared. Williams *et al.*[91] reported a case of coagulum formation at the tip of their specially devised catheter for coronary arteriography. This apparently was the cause of coronary artery occlusion and infarction. A continuous injection of physiologic saline solution with or without heparin has been recommended in order to prevent coagulation within the catheter.

When a catheter is introduced into a small artery (*e.g.*, the brachial artery), spasm may develop.[13,20,52,78,84,89] This spasm may be so intense that further examination is impossible. Various vasodilators as well as brachial plexus block have been used in order to relieve such a spasm.

The tip of the catheter may block a small artery during aortography or coronary arteriography. If one of the coronary arteries is blocked and contrast medium is injected, serious complications may result. It is recommended that the tip of the catheter be placed a few centimeters above the valves.[13,39,51] Another method of preventing this is by monitoring the catheterization by means of electrocardiographic control.[91]

A subintimal injection of contrast medium may result if the terminal opening of the catheter is directed against the inner wall of a large artery.[65]

Complications Due to the Contrast Medium. The brain and the kidneys are susceptible to varying concentrations, amounts, and types of contrast media. It has been shown that iodopyracet (diodrast) and sodium acetrizoate (triurol, urokon, rheopak) produce more complications than salt of diatrizoate (hypaque, urografin, renografin, cardiografin).[8,14–16,43,44,88] Lindgren and Törnell[55] demonstrated that high concentrations of contrast media are more dangerous than large amounts of low concentration. Edling *et al.*[24] performed retrograde aortography by femoral catheterization on dogs and found no signs of damage to normal kidneys when using large amounts of high concentration doses of sodium diprotrizoate (miokon) or a salt of diatrizoate (urografin). Berg, Idbohrn, and Wendeberg[8] studied the kidneys of rabbits and also reported no damage using the latter salts (urografin or hypaque). However, when they used miokon in a 50 per

cent solution or lower concentrations of iodopyracet and sodium acetrizoate, kidney damage was noted.

The complications with hypaque or urografin (renografin) are less than those noted with other contrast media. With these newer types, no cases of kidney damage in man have been reported. The earlier contrast media produced many cases of renal failure.[3,44,56,70]

The diatrizoate salts are not completely free from side effects. These have been demonstrated by experimental perfusion studies[55] and, in coronary arteriography, by the development of associated electrocardiographic changes.[4,22,28,91] Because of the electrocardiographic changes caused by hypaque, Dotter and Frische[22,31] recommended the use of thorotrast in coronary arteriography, a contrast medium known not to produce any electrocardiographic changes. Fabrikant *et al.*[28] were of the opinion that electrocardiographic changes were of no consequence when using 50 per cent hypaque, and that, consequently, there was no justification for using thorotrast.

In selective angiography the contrast medium reaches the tissues in higher concentrations with a greater risk of damage. Thus, accidental injection of large amounts of highly concentrated contrast medium into the renal arteries and the mesenteric arteries has produced extensive damage to the kidneys and bowels, respectively, and even fatalities.[57,87] The experimental studies of Edling, Helander and coworkers[24–27] on dogs caused selective renal angiography to fall into disrepute. These authors showed that injections of large amounts of highly concentrated contrast media of the iodopyracet or sodium diprotrizoate groups into the renal artery caused irreversible damage to the renal parenchyma. They produced a long-standing, pathologic nephrogram in kidneys which then showed decreased clearance values as well as pathologic lesions in the form of small cortical infarctions. In some cases a normal nephrogram was obtained with smaller amounts of contrast media. There was still, however, a depressed clearance value following angiography.

ARTERIOGRAPHIC CATHETERIZATION TECHNIQUES USED IN THE PRESENT STUDY

The arteriographic techniques here presented are based on approximately 1,000 studies performed percutaneously in the Roentgen-Diagnostic Department of the University Hospital of Lund.

PRINCIPLES

The method of preference to demonstrate an area or organ as selectively as possible is arterial catheterization. In order to use all its potentialities, each detail of the angiographic technique is important. The radiologist should perform the entire study, since the technical performance influences every step of the examination. There is no longer any justification for using a cutdown approach when the percutaneous method can be so consistently and successfully applied.

PREPARATION OF THE PATIENT

The patient is given a light diet, cathartics, and cleansing enemas as indicated. A preliminary survey roentgenogram is made of the area to be studied (abdomen, chest, etc.).

The kidney function should be within normal limits for any type of angiographic study. One cc. of the intended contrast medium can be injected intravenously at least twenty-four hours before the examination to test for any allergic responses.

One hour before the study, the patient is given a mixture of morphine and scopolamine or phenobarbital depending on the age and size. A general anesthetic is used only for children.

A local anesthetic is usually employed at the puncture site.

EQUIPMENT

A sterile table is set up having a container with guide wires of different lengths and diameters, puncture needles, sterile metal bowls and towels (Fig. 1).

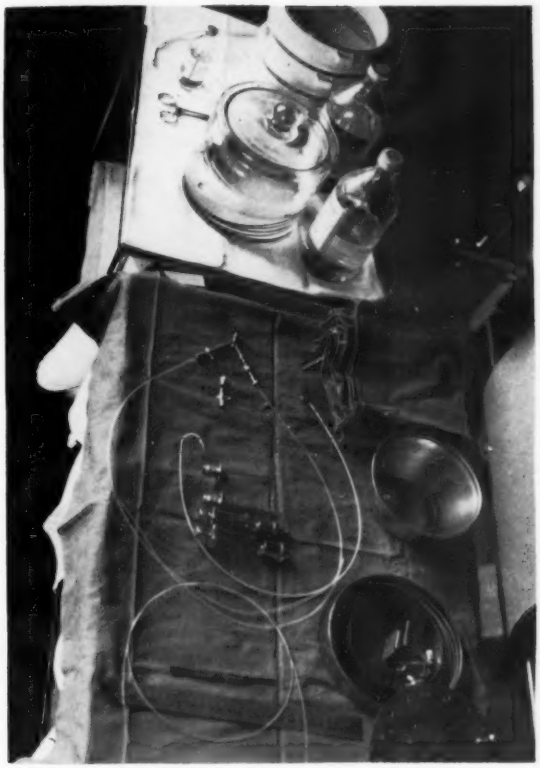

Fig. 1. Sterile table with container having various sizes of guides, Seldinger needles, and Luer-Lok adapters. Note Y-adapter for simultaneous injection via two catheters and large bore catheter with preshaped bends.

The various catheters are stored in containers with bactericidal solutions. The most suitable catheter is selected with special attention given to length, diameter, and type for the particular vessel and region to be studied. At present, the polyethylene catheters most used are sizes PE 160 (outer diameter 1.57 mm., inner diameter 1.14 mm.) and PE 205 (outer diameter 2.08 mm., inner diameter 1.57 mm.), each having a guide wire of the appropriate size. Polyethylene catheters with a larger bore (PE 240 and PE 260) can also be introduced percutaneously if the tip is tapered.[91]

The radiopaque catheter of Ödman is the most useful in percutaneous selective angiography. Three types of catheters were developed: (1) the large bore (yellow: outer diameter 2.85 mm., inner diameter 1.5 mm.); (2) the medium bore (green: outer diameter 2.4 mm., inner diameter 1.3 mm.); and (3) the small bore (red: outer diameter 2.0 mm., inner diameter 1.15 mm.). Studies of the characteristics and flow rates of these catheters have been made.[1,65] The radiopaque catheter tip must be tapered. If a branch of the aorta is to be studied selectively, the catheter is shaped accordingly by the application of heat.

The catheter is washed through with physiologic saline solution. The guide wire is passed through the catheter to check for ease of passage. The projecting end of the guide is measured when the tips of the catheter and guide are even. Thus, if necessary, the guide can be replaced to the same length when the catheter is within a vessel.

Method of Catheter Introduction

In the case of the femoral artery, the needle is inserted just distal to the inguinal ligament, and, in the brachial artery, at the level of the elbow joint.

Femoral artery catheterization is preferred to the brachial because the larger caliber of the former permits the introduction of a larger catheter without the risk of spasm. Brachial artery catheterization is, therefore, used only in these instances: (1) angiography of the subclavian artery and its branches; and (2) when it is impossible to reach the region to be studied by the femoral route, *e.g.*, advanced tortuosity or complete occlusion of the aorta due to atheroma or coarctation.

Both arteries are well fixed to the surrounding tissue in the regions mentioned and are, therefore, easy to puncture. The arteries are accessible for compression following the examination, thus preventing hematoma formation. In obese patients the femoral artery is best palpated immediately proximal to the inguinal ligament but, if punctured in this region, an uncontrollable bleeding may occur into the retroperitoneal space.

When the artery is punctured percutaneously and a good blood flow is obtained, a guide wire is passed down the cannula into the artery. The guide must pass easily

through the artery. Occasionally a slight resistance is felt when the tip of the guide enters the arterial lumen and meets the opposite wall. In inexperienced hands the guide may perforate the opposite arterial wall and, in spite of local anesthesia, the patient will feel pain and may develop signs of shock. It is important, therefore, that not even the slightest resistance be felt during the introduction of the guide wire. There is also a risk of breaking off the flexible tip of the guide if the introduction is forced. The patient is instructed before the examination to notify the radiologist of any pain.

Once the guide is in the iliac artery it should be easy to pass it up into the aorta. The tip of the guide may not pass the bifurcation of the aorta if there is a marked tortuosity. It should not be forced. The guide should be removed and replaced by a more flexible one, preferably one made of nylon or of wire with links.[35,36] On occasion, insertion from the opposite femoral artery is necessary to bypass an obstruction. In those instances where it is impossible to catheterize by the femoral route, the brachial artery is used.

The guide should be removed as soon as possible because of the possibility of coagulum formation on the rough surface. While the catheter is in the artery, small amounts of physiologic saline solution are injected to keep it patent.

A nonopaque polyethylene catheter is preferred whenever it is possible to place the catheter in a vessel without preshaping. The outer diameter of a nonopaque catheter is smaller than that of a radiopaque catheter with a comparable lumen. The trauma to the femoral artery will thus be less. The smooth surface of the nonopaque catheter decreases the risk of clotting. The amount of contrast material delivered per unit time under the same injection pressure will be greater than with an opaque catheter of comparable outer diameter, thus resulting in increased contrast density. In cases where the femoral artery is small and has a tendency to go into spasm (*e.g.*, in children), the PE 160 catheter is preferred.

Selective angiography of the left heart chamber as well as of most branches of the aorta can be performed via the femoral route. The major prerequisite is that the catheter be shaped according to the topography of the aorta and the vessel to be catheterized.

Following the introduction of the catheter, the tip is positioned under fluoroscopic control or, preferably, using the image intensifier and a closed circuit television setup.

Once the study is completed, the catheter is removed and manual compression or pressure by a special balloon is used for at least ten to fifteen minutes over the puncture site. A careful selection of the puncture site with effective compression will prevent any excessive bleeding following the examination.

REGIONS STUDIED IN THE PRESENT INVESTIGATION

HEART

Left Heart Ventriculography. This procedure is usually carried out under general anesthesia. The yellow radiopaque catheter and the smaller diameter guide wire are used. The catheter tip is tapered so that the terminal hole has a bore of the same diameter as the guide. Four to six side holes are punched near the tip to counteract recoil during injection. A 30 degree bend near the tip facilitates passage through the aorta in the region of the left subclavian artery and centers the tip so that it will pass more easily beyond the aortic valves. The remainder of the catheter follows a course along the anterior wall of the aorta (Fig. 2, *A* and *B*). The guide wire is removed once the catheter is in the aorta and then the catheter tip is placed in the left ventricle under fluoroscopy. About 10 cc. of contrast material is injected manually to check for position and also to make certain that the tip is not lying against the endocardium. Continuous electrocardiographic control (preferably oscilloscopic) should be used. If the patient is intubated, the intrabronchial pressure is raised to slow the heart rate while 50 cc. of 76 per cent uro-

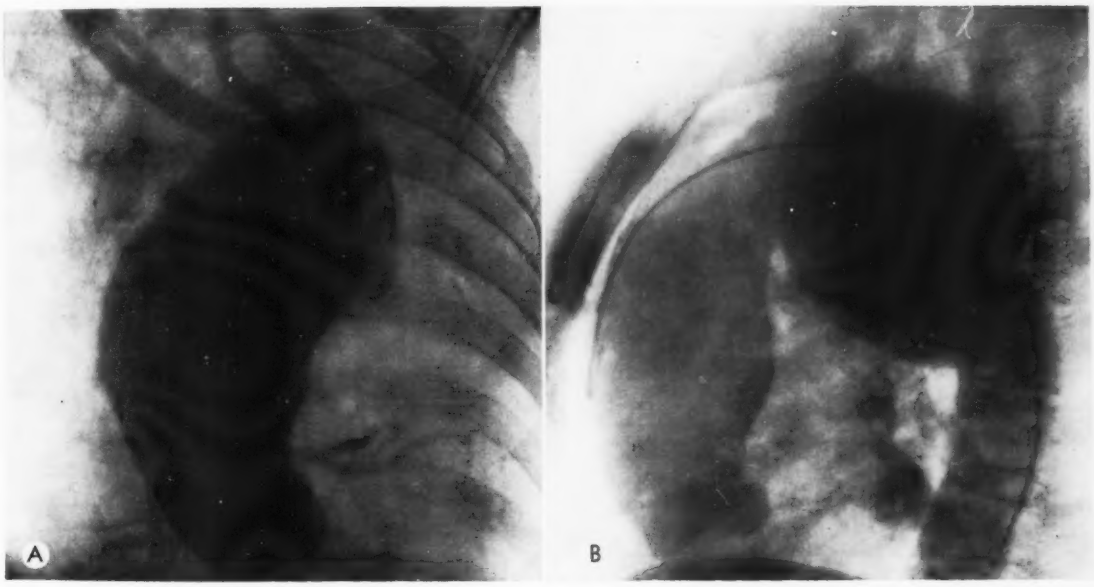

Fig. 2. (*A* and *B*) Thoracic aortograms made by using a nonopaque catheter (PE 205) via the femoral artery Aneurysm of the arch and ascending part of the aorta is demonstrated. Observe that the catheter follows the anterior wall of the aorta.

grafin (renografin) or 90 per cent hypaque at 39° C. is injected (7–8 kg./cm.^{2}).

Coronary Arteriography. The PE 205 nonopaque catheter containing the guide wire, with their tips even, can be seen by fluoroscopy in the thoracic aorta. Sometimes it is impossible to pass beyond the level of the left subclavian artery. The catheter is then removed, leaving the guide in place. A bend is made a few centimeters from the tip by heating, and the catheter is reinserted.

The tip of the catheter is positioned 2–3 cm. above the aortic valves. Thirty cc. of 60 per cent urografin or 45–50 per cent hypaque are injected (4 kg./cm.^{2}) during diastole. The heart rate may be slowed down by raising the intrabronchial pressure. Another method in use at this department since 1956,[69] also reported by Hase and Deterling[40] and Richards and Thal,[79] is the triggering of the contrast injection by the R-wave through the electrocardiograph, thus injecting the contrast medium during diastole.

AORTA AND PELVIC ARTERIES

Thoracic Aortography. The PE 205 catheter is introduced as in coronary arteriography. The tip is positioned 5 cm. above the aortic valves in order to reduce the risk of direct coronary artery injection and valve trauma (Fig. 2, *A* and *B*).

In the case of a suspected coarctation, two PE 160 nonopaque catheters are used, one being introduced from each brachial artery. The tip of the catheter from the right brachial artery is positioned in the ascending aorta, while that from the left side is placed in the descending aorta just above the stenosis (Fig. 3). The other ends of the catheters are connected together by a Y-adapter (Fig. 1) to the automatic injector and 40 cc. of 60 per cent urografin or 45–50 per cent hypaque is injected (4–5 kg./cm.^{2}).

Abdominal Aortography. The PE 205 catheter is introduced via the femoral route to approximately 30 cm. from the inguinal ligament. The guide wire is then removed and the catheter is filled with contrast medium (2 cc. for an 80 cm. long PE 205 catheter) and a single anteroposterior abdominal roentgenogram is made to locate the position of the catheter tip.

For aortic renal angiography, the catheter tip is positioned at the middle of the body of the second lumbar vertebra. The renal arteries branch from the aorta at a

FIG. 3. Thoracic aortogram demonstrating coarctation of the aorta. Two PE 160 catheters were introduced percutaneously by the brachial route. The left catheter (arrow) is above the stenosis; the right is in the ascending aorta.

point above this equal to the thickness of about one vertebral body. The bolus of the contrast medium (30 cc. 60 per cent urografin at 4 kg./cm.^{2}) will reach all renal arteries with a minimal filling of the celiac axis and superior mesenteric artery (Fig. 4). This method gives an even distribution of contrast medium in both renal arteries and allows a comparison of the renal blood flows. If the aorta is wide and tortuous, the tip of the catheter must be placed slightly higher to allow for the recoil of the catheter into the aortic curves during the injection phase.

With the development of selective catheterization techniques, abdominal aortography is now used for: (1) renal angiography in cases where the kidney is usually supplied by more than one artery (malrotated and dystopic kidneys, double kidneys, and hydronephrotic kidneys); (2) cases with suspected suprarenal tumors; (3) those cases where selective angiography fails and the radiopaque catheter can easily be exchanged with a PE 205 nonopaque catheter; (4) cases where a comparison of the renal arteries is desired;[45,90] and (5) patients with hypertension and a suspected narrowing of a renal artery. According to Poutasse,[73] the lesion is usually localized to the origin of the renal artery and is often bilateral. In selective renal angiography the tip of the catheter may pass beyond the lesion and thus fail to demonstrate it.

If it is impossible to reach the abdominal aorta by the femoral route, a red radiopaque catheter is then introduced from the left brachial artery. The catheter is preformed with a 45° bend 4–5 cm. from the tip so that it will pass into the descending aorta. Contrast injection with the blood stream requires a larger amount of contrast medium under a higher pressure. About 40 cc. of 60 per cent urografin at 6 kg./cm.^{2} is used. In occlusive disease of the aorta a smaller amount at a lower pressure is used (20 cc. of 60 per cent urografin at 4 kg./cm.^{2}).

Pelvic Arteriography. The PE 205 nonopaque catheter is inserted via the femoral

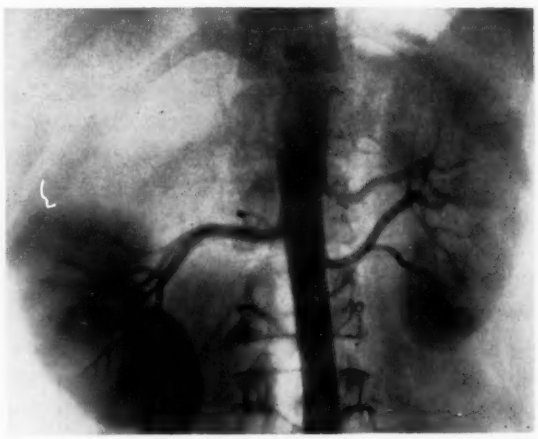

FIG. 4. Aortic renal angiogram shows that the right kidney, supplied by one artery, is displaced downward by a large suprarenal benign tumor; the left kidney is supplied by three arteries. The tip of the catheter is placed at the middle of the body of L-2.

route to the level of the aortic bifurcation (about 20 cm. from the inguinal ligament) and 20 cc. of 60 per cent urografin is injected (4 kg./cm.^{2}). Compression of both femoral arteries during the injection increases the contrast density in the pelvic region. Both femoral arteries can also be studied in this manner for arterial occlusive disease.

BRANCHES OF THE AORTA

Subclavian Arteriography. A PE 160 catheter is introduced by the brachial route and the tip is placed a few centimeters distal to the origin of the subclavian artery. About 10 cc. of 45 per cent hypaque is injected at 2 kg./cm.^{2} (Fig 5*A*). This method is used in cases where there is no sign of primary arterial disease (thrombosis or arteritis).

Where there are signs of occlusive disease of the subclavian or brachial arteries, catheterization of the subclavian arteries is performed via the femoral route. Different preshaping of the catheter is necessary for the left and right subclavian arteries. For the *left* subclavian, a green catheter with a single terminal hole and a bend of 30° a few centimeters from the tip is used to bypass the vertebral artery. The same amount of contrast material and pressure is used as previously mentioned (Fig. 5*B*). For *right* subclavian arteriography, the catheter is S-shaped, one curve for the aorta and one for the innominate artery (Fig. 6). It is often difficult to catheterize the right subclavian artery because the tip tends to pass into the common carotid artery. A short bend in a lateral direction at the tip may sometimes help. If it is impossible to catheterize the subclavian artery, then the tip is placed in the innominate artery in the region of the orifice of the subclavian artery and 20 cc. of 45 per cent hypaque is injected at 2.5–3.0 kg./cm.^{2}.

Selective Angiography of Abdominal Vessels. It is important to know the topographic relationship when studying the branches of the abdominal aorta selectively. The renal arteries arise from the lateral wall of the aorta at the level of the disk space between L-1 and L-2 with a variation of one vertebral body caudally or cephalically. The superior mesenteric artery and celiac axis arise from the ventral part of the aorta about 0.5–3.0 cm. and 1.0–4.0 cm., respectively, above the origin of the renal arteries.[17] Before the examination, a lead indicator is placed on the back in the midline at approximately the level of the disk between L-1 and L-2. A plain anteroposterior roentgenogram of the spine will localize the indicator.

A small or medium bore radiopaque catheter is used for the renal arteries and a medium or large bore for the ventral bran-

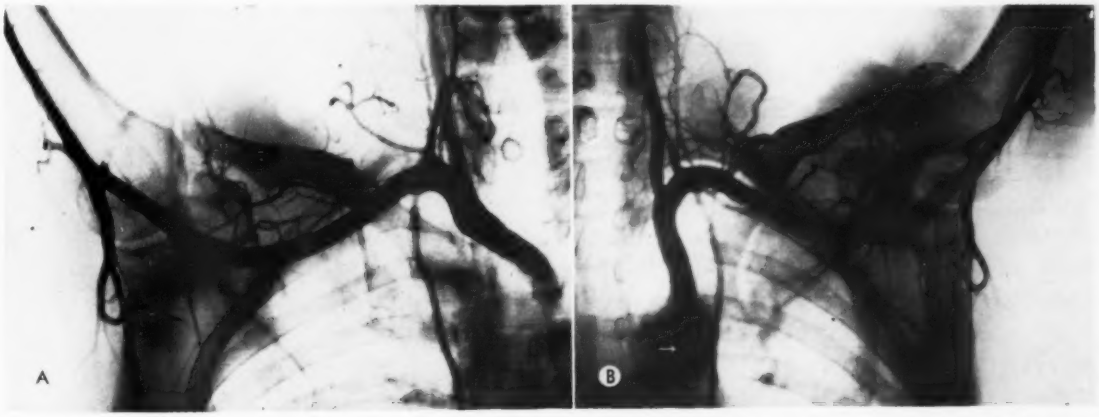

Fig. 5. (*A*) Normal right subclavian arteriogram. A PE 160 catheter was introduced by the brachial route. Note the small vertebral artery. (*B*) Left subclavian arteriogram of the same case. A radiopaque catheter (arrow) was introduced by the femoral route. Observe the wide vertebral artery.

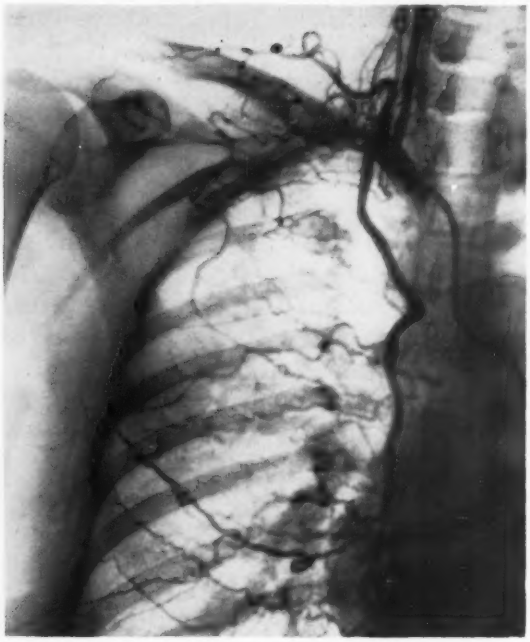

FIG. 6. Right subclavian arteriogram made using a radiopaque catheter introduced via the femoral artery. Thrombosis of the subclavian artery with well-developed collateral circulation is shown.

ches. The end of the catheter is tapered so that a small guide wire can pass through it and then the necessary bends are preshaped. Side holes are not used in the catheter for selective studies.

In *selective renal angiography* the catheter must have a bend at the tip, the arc of which is slightly larger than the diameter of the aorta. This provides easy introduction and positioning in the renal artery. In young, slender people, especially women, the bend near the tip of the catheter must not have an arc greater than 1 cm. in diameter; while in elderly people (*i.e.*, tall arteriosclerotic men), the arc must be at least 3–4 cm. (Fig. 7). The angle formed by the terminal portion of the bend and the long axis of the catheter is determined by the course of the renal artery from the aorta to the renal hilus.[11] In low-lying kidneys the renal artery has a steeply descending course and requires an acute angle near the catheter tip which parallels the long axis (Fig. 8). In about 10 per cent of all kidneys a branch arises early from the renal artery. Therefore, the tip of the catheter must be placed just within the origin from the aorta in order to prevent nonfilling of this branch. Either femoral artery may be used for the puncture but the shaping of the proximal curve of the catheter is different for the ipsi- or contralateral renal arteries.[63] If the tip of the catheter cannot be placed in the renal artery, then a small injection of contrast material will reveal a tortuosity of the aorta or any other anatomic changes. The guide wire is reinserted and the catheter is removed for the forming of new bends as determined by the aortic pattern. Occasionally the tip of a small catheter can enter a lumbar artery but then there is little or no return blood flow through the catheter. As a check, 10 cc. of physiologic saline solution injected down the catheter will produce back pain, while, if the tip is in the renal artery, no pain is experienced.

In a person with a normal functioning kidney of good size (measured during urog-

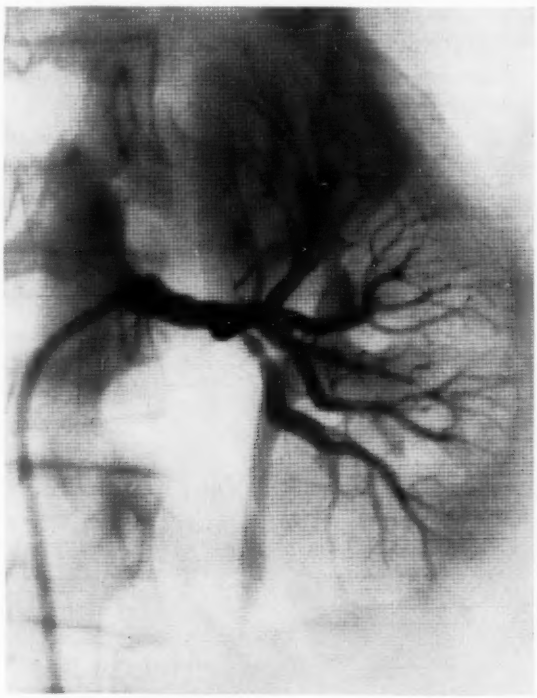

FIG. 7. Selective renal arteriogram of the left kidney. The tip of the catheter is too long for the small diameter aorta.

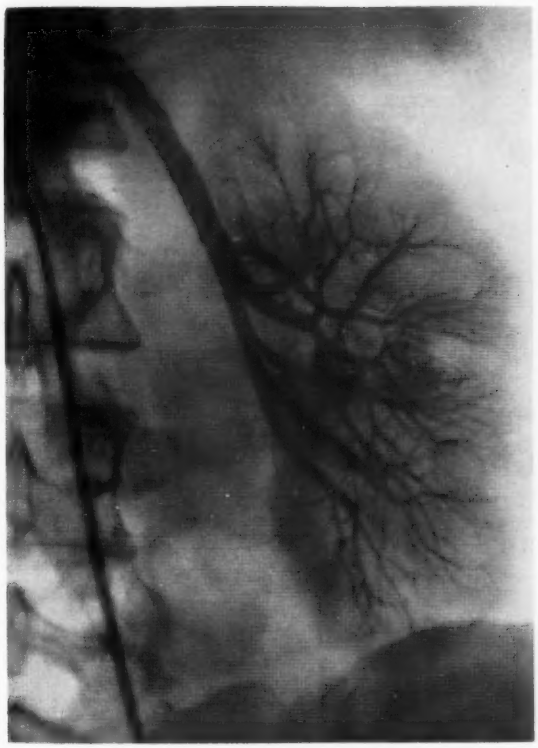

Fig. 8. Selective renal arteriogram of a low-lying kidney. Observe the acute bend of the catheter tip.

raphy), the medium bore (outer diameter 2.4 mm.) catheter will not obliterate or cause spasm of the renal artery (about 5 mm. in diameter). If the kidney size is reduced or if function is abnormal, the smallest catheter (2.0 mm.) must be used. Contrast medium is injected only if there is a normal blood return through the catheter and therefore it is important not to have side holes (Fig. 9, *A* and *B*).

The amount of contrast medium to be injected is dependent upon the amount of functioning kidney parenchyma. In a small poorly functioning kidney, 3 cc. of 45 per cent hypaque is sufficient. In a normal functioning kidney, 5 cc. of 45 per cent hypaque is injected, while in a kidney with a large tumor 8–10 cc. might be required. The injection pressures range between 2.0 and 2.5 kg./cm.^{2} (5 cc./sec.). The electrocardiographic injection control system is used because the blood flow is less in diastole and no blood stream lines will appear in the contrast medium.

Selective studies of the *celiac axis* and *superior mesenteric arteries* require a medium or large bore catheter with the terminal bend having a larger arc than that used in renal angiography. This is because of the greater diameter of the aorta above the region of the renal arteries. A curve is preshaped for the normal lordosis and another proximal bend at right angles for the aortic bifurcation. The level of the renal arteries is first localized by introducing the tip of the catheter into one of the orifices under fluoroscopy or using the image intensifier. The level is noted and the catheter is withdrawn. The tip is rotated anteriorly and the catheter is inserted further. The tip should now easily enter one of the two ventral arteries. A small amount (5–10 cc.) of contrast material is injected under fluoroscopic control. The vascular pattern will reveal which artery has been catheterized. If there is difficulty catheterizing one of the ventral arteries, then an injection should be made into the aorta and the catheter should be reshaped to conform to the actual shape of the aorta.

Once the catheter is in place, 30 cc. of 60 per cent urografin (renografin) is injected under a pressure of 2.5–3.0 kg./cm.^{2} (10–15 cc./sec.).

Vertebral angiography is performed in younger patients by catheterizing the left vertebral artery via the femoral route with the PE 205 catheter containing the guide wire. This can easily be seen in the cervical region by fluoroscopy. In adults, vertebral angiography is usually performed by the direct percutaneous method. In patients under the age of forty, the catheter tip will usually pass directly into the left vertebral artery.[19] If the catheterization is unsuccessful in the first few minutes, the catheter and the guide wire must be retracted. An injection before withdrawal of the catheter from the subclavian artery will help elucidate anatomic variations, *i.e.*, a small vessel, absent artery on the left side, marked tortuosity of the vertebral artery, etc.

Catheterization of the right vertebral artery is attempted by the brachial route

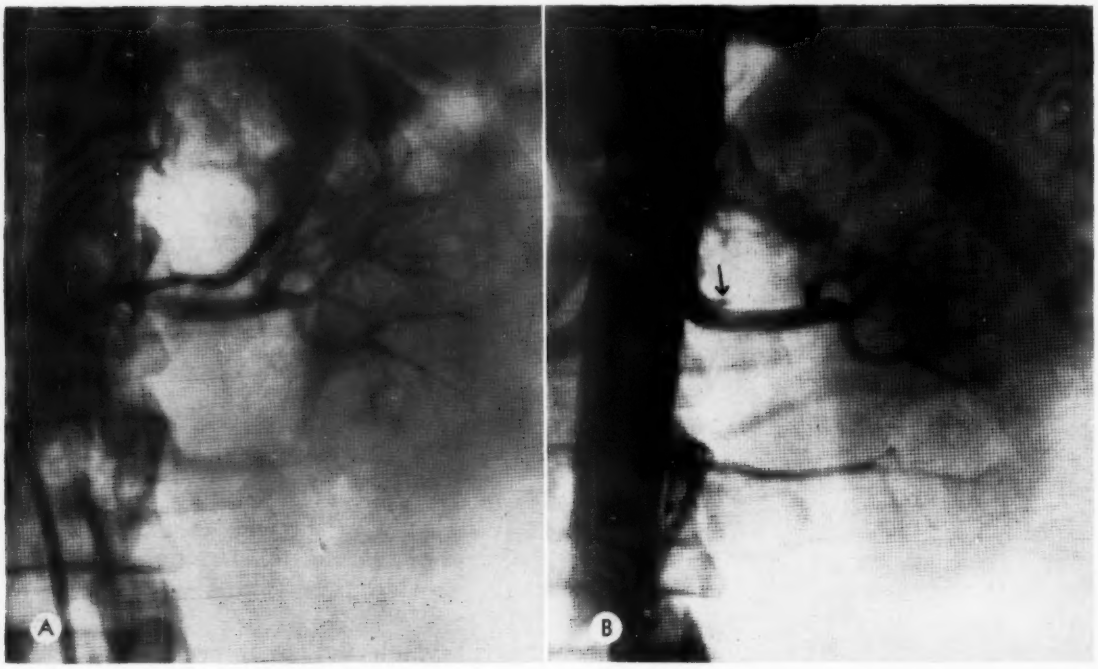

FIG. 9. (*A*) Selective renal arteriogram with the tip of the catheter introduced into a branch supplying part of the upper pole. Observe the normal flow from the catheter because of side holes near the tip. (*B*) Aortic renal angiogram of the same case a week later. The upper polar branch (arrow) is occluded as a result of the previous catheterization.

in younger patients before the direct percutaneous vertebral puncture method is used. In this case, a red radiopaque or a PE 160 nonopaque catheter is used with a bend about 1 cm. from the tip. It is easier to introduce the tip of the catheter into the right vertebral artery than into the left from the brachial route because of the perpendicular course of the vertebral artery in relation to the subclavian. On the left side, the vertebral and subclavian arteries form an acute angle (Fig. 5*B*). Manual injection of 5 cc. of 45 per cent hypaque is used.

DISCUSSION

Based on experience gained from approximately 1,000 cases we may affirm that the percutaneous arteriographic catheterization technique is relatively simple if certain precautions are taken.

Most complications can be avoided by adhering to certain principles. The catheter used in the percutaneous technique requires a terminal hole in the tip. In some angiographic studies, *e.g.*, left heart ventriculography, there is a danger of subendocardial injection of contrast material through the terminal hole with the high pressure used and, therefore, a test injection should be made. There may also be a recoil of the catheter during the injection. Catheters with side holes placed only near the tip are used to overcome this in angiocardiography and left heart ventriculography. With the percutaneous method, four to six side holes are punched in the catheter and the terminal hole is reduced by tapering to fit the small guide wire.

Side holes near the tip of the radiopaque catheter have also been recommended for aortography and selective arteriography.[1,38,63–65] It has, however, been our experience that the polyethylene catheter should never have side holes except for left or right heart catheterization. Contrast material may be injected subintimally into the aorta (Fig. 10) or an occluded branch during selective angiography.

The most advanced renal lesions in experimental selective renal angiography were caused by contrast medium being injected into an anoxic kidney. Coagulum formation may occur at the catheter tip and, when the medium is injected, may throw off an embolus. If the catheter has no side holes and if the contrast material is injected only when there is a maximum return of blood, such complications can be avoided.

Chemotoxic lesions have been produced in the kidney by contrast media used in experimental selective renal angiography on dogs. These changes can be explained, first, by the toxicity of the contrast media used and, second, by the large amounts of contrast medium used in relation to the size of the kidneys. Therefore, these studies cannot be applied directly to man, especially since the diatrizoate salts, which have been shown to be practically nontoxic, were not used.

The present technique of selective renal angiography via the femoral artery using the diatrizoate salts (hypaque, urografin, renografin, etc.) has been employed in more than 200 cases and there have been no signs of renal damage due to these newer types of contrast media.

Fig. 10. Aortic renal arteriogram made using a radiopaque catheter intended for selective renal arteriography. The catheter contained side holes and therefore a good return flow was noted. Observe that part of the contrast material was injected subintimally via the terminal hole.

SUMMARY

The present technique of arteriography is to study the vessels as selectively as possible. The development of arteriographic catheterization techniques and the complications are reviewed.

Experiences with percutaneous arteriography, based on approximately 1,000 cases, performed at the Roentgen-Diagnostic Department of the University Hospital, Lund, Sweden, are described.

Two puncture sites are suitable for the percutaneous introduction of a catheter: the femoral (which is preferable) and the brachial arteries.

Different types of catheters (non- or radiopaque) are used, depending on the puncture site and the vascular regions which are to be studied. The catheters as well as the amounts and types of contrast media and the injection pressures are described.

When complications arise they are often due to inexperience in the use of these techniques. These complications may be at the puncture site, or they may be due to the guide wire, catheter or contrast medium. Only the salts of the diatrizoate (hypaque, urografin, renografin, etc.) should be used. If the above mentioned precautions are taken, percutaneous catheterization arteriography is a safe and valuable procedure which is relatively simple to perform.

Erik Boijsen, M.D.
Department of Diagnostic Radiology
Lunds Lasarett
Lund, Sweden

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A SIMPLE ISOTOPE DILUTION TECHNIQUE FOR QUANTITATIVE DETERMINATION OF LEFT TO RIGHT SHUNTS*

By K. AMPLATZ, M.D., J. MARVIN, Ph.D.,† P. WINCHELL, M.D., G. GOMEZ, M.D., P. ADAMS, M.D., *and* R. G. LESTER, M.D.
MINNEAPOLIS, MINNESOTA

SMALL isolated left to right shunts constitute a fairly large percentage of congenital cardiac defects. At this time it is not definitely known whether these patients have a normal life expectancy. As the surgical mortality rate decreases, the presence of a known intracardiac defect might become an indication for correction. This is now generally accepted for cases of patent ductus arteriosus.

Oximetry, the most widely used diagnostic method, does not allow the detection of small left to right shunts or shunts with balanced pressures. This relative lack of sensitivity is mainly due to: (1) varying oxygen content of caval blood coming from different organs (renal, hepatic, azygos, etc.); (2) lack of complete mixing of venous blood in the right heart (streamline flow); (3) different flow rates in the superior and inferior vena cava; and (4) changes in the metabolic state during catheterization (crying, etc.). The obtained values, therefore, are sometimes confusing, and in many cases the results are of questionable significance.

In recent years other more accurate methods to detect left to right shunts have been developed. Sanders and Morrow[6,7,8] used the large arteriovenous difference which exists following the continuous inhalation of an inert gas (nitrous oxide or radioactive krypton) to diagnose arteriovenous shunts. They found their test to be superior to oximetry in a large number of patients. Case *et al.*[3] employed the same principle in animal experiments using radioactive ethyl iodide. Swan and Wood[10] demonstrated that small left to right circulatory shunts can be detected by recording dye dilution curves from the right heart following the injection of an indicator into the left heart. Based on this same principle we have developed a very simple, highly sensitive test which has proved to be more accurate than oximetry in a large group of patients at the University of Minnesota Heart Hospital.

BASIC PRINCIPLE

With a single inhalation a minute amount of a radioactive gaseous indicator (methyl iodide 131) is introduced as a "bolus" into the left atrium and from there passes into the left ventricle and then the aorta. In the presence of a left to right shunt, radioactive blood appears in the right heart almost immediately (one to three seconds) following the inhalation. In the absence of a shunt, at least six seconds elapse before radioactivity appears in the right heart. Small blood samples (0.3–1.0 cc.) are obtained through a cardiac catheter from the right heart by means of an automatic sampler, which draws samples at two second intervals. The obtained blood samples are counted in a standard well scintillation counter, and the values of radioactivity are plotted as a curve. In the presence of a left to right shunt there is an abrupt and steep rise in the radioactivity curve several seconds before the normally and slowly rising radioactivity curve of the venous return (Fig. 1).

The diagnosis of an existing left to right shunt can be established from these curves three ways. (1) The appearance time of radioactivity of the shunt curve is always shorter than that of the venous return curve. (2) The short, abrupt peak of the

* From the Departments of Radiology, Pediatrics and Medicine, University of Minnesota Hospitals, Minneapolis, Minnesota.
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† Deceased.

left to right shunt curve is distinctly different from the gradual slope of the venous return curve. (3) The venous return curve is invariably lower than the left to right shunt curve due to diffusion of methyl iodide into extravascular spaces in the peripheral capillary bed. We have found this to be true in even very small left to right shunts.

LOCALIZATION OF SHUNTS

The first study is usually made with the catheter in the pulmonary artery. If the radioactivity values in the obtained blood samples indicate a normal venous return, no additional inhalations are necessary and the catheterization may be concluded. If a shunt is demonstrated, additional inhalations must be made at the right ventricular and/or right atrial levels in order to localize the shunt. Using a double lumen catheter, one may sample simultaneously from two cardiac chambers. Sampling from the superior or inferior vena cava is not necessary unless anomalous venous return to the vena cava is suspected. Since radioactive methyl iodide is a highly diffusible substance and is not excreted through the lung, the blood radioactivity is quickly stabilized, and the study may therefore be repeated in different cardiac chambers almost immediately.

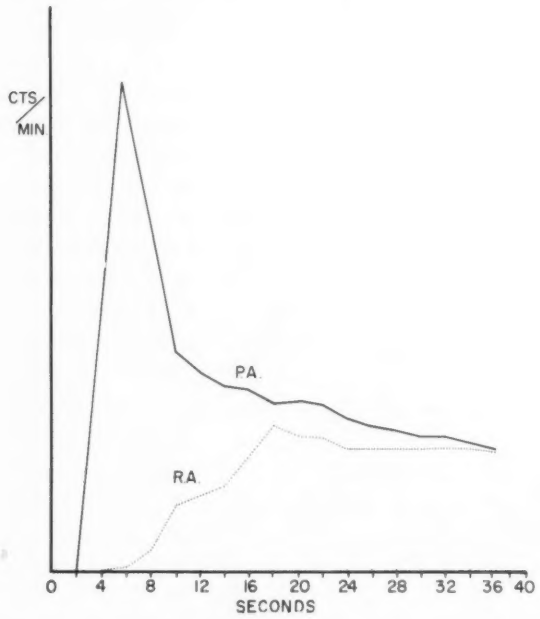

FIG. 1. Small left to right shunt which was not demonstrated by oximetry. Shunt curve from pulmonary artery, venous return curve from right atrium.

QUANTIFICATION OF SHUNT

Stewart[9] and Hamilton and Remington[5] have shown that the cardiac output is calculated from indicator dilution curves by dividing the dose of the injected indicator by the area under the primary curve. Since the inhalation of radioactive methyl iodide is in essence an injection of an indicator substance into the left heart, the dilution curve from a systemic artery can be used to compute cardiac output by the same principle. The diffusion of methyl iodide into extravascular spaces occurs primarily in the peripheral capillary bed; consequently, the dilution curves obtained from a systemic artery or the shunt curves from the pulmonary artery, which are likewise proximal to the capillary bed, are considered to be representative and undistorted.

In a patient with a left to right shunt, simultaneous dilution curves obtained from the pulmonary artery and femoral artery are almost identical in configuration (Fig. 2), and their area is directly related to the size of the shunt:

$$\frac{\text{shunt flow}}{\text{pulmonary flow}} = \frac{\text{area pulmonary artery curve}}{\text{area femoral artery curve}}.$$

As the total pulmonary flow is also cardiac output plus shunt flow, the amount of shunted blood can easily be expressed in ml. per minute or percentage of peripheral flow. Because of the high solubility of methyl iodide 131 in the bronchial mucosa, a correction factor must be used, taking into consideration that only 50 per cent of the methyl iodide is immediately transferred in the pulmonary alveolar bed.

Since cardiac output can also be calculated from the surface area of the patient or from the Fick principle,[4] one can easily

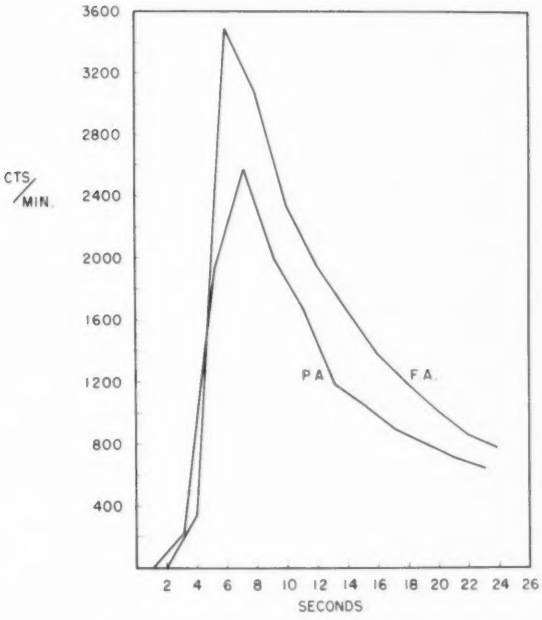

Fig. 2. Left to right shunt with simultaneous curves from the pulmonary artery and femoral artery.

compute the area under the femoral curve without actually obtaining samples. The shunt flow can, therefore, be calculated without drawing arterial samples, which is a decided advantage in patients in the pediatric age group.

PHYSICAL PROPERTIES AND METABOLISM OF METHYL IODIDE 131

Radioactive methyl iodide was chosen as an indicator substance because this gas has certain unique properties. Thode *et al.*[11] have used this substance for inhalation radiocardiography. These authors have shown that in order to approach toxic levels one would have to use two hundred thousand times the amount used during one of these tests. Methyl iodide 131 is a yellow liquid with a boiling point of 42.5° C. and evaporates readily at room temperature. This radioactive gas is easily prepared.[2] Basically, one to two drops of stable methyl iodide are added to radioactive sodium iodide in a bottle which is closed with a rubber stopper. This is adequate to examine approximately 500 patients. Because of the decay of iodine 131 (half life, eight days), the solution must be renewed monthly.

In the body the methyl iodide molecule is hydrolyzed, and free iodine ions circulate; consequently, there is no significant exhalation of methyl iodide through the lungs, making the use of this gas safe to the operator. If the thyroid gland has been blocked with stable iodine (Lugol's solution or potassium iodide), the radioactive iodine ions are excreted fairly rapidly through the urine (Table 1). Numerous excretion studies in humans and animals have shown the biologic half life to be six to ten hours. Usually 85 to 95 per cent of the radioactive material is recovered in the urine in a period of thirty-six hours.

Since iodine 131 is an emitter of hard gamma rays, the blood samples are counted in a standard well scintillation counter with high efficiency, thus allowing the use of a very low tracer dose. Usually 3–8 μc is given per inhalation, depending on the age of the patient, whith no significant radiation hazard to the patient or the operator.

TECHNIQUE

On the day of the catheterization, small stainless steel tubes are charged with 0.5–4.0 cc. of methyl iodide 131 gas. These tubes are taken to the catheterization laboratory and counted, with the scintillation counter at a fixed distance, in order to determine the exact dosage contained therein. The patient's head is placed under a small, constantly evacuated acryllic hood (A in Fig. 3). The air from this hood is drawn through a small carbon filter which absorbs the uninhaled methyl iodide 131 quantitatively. After the test is completed,

Table I

TOTAL EXCRETION OF I^{131} IN THE URINE WITH THE THYROID BLOCKED

6 hours	50%
12 hours	75%
24 hours	87%
36 hours	94%

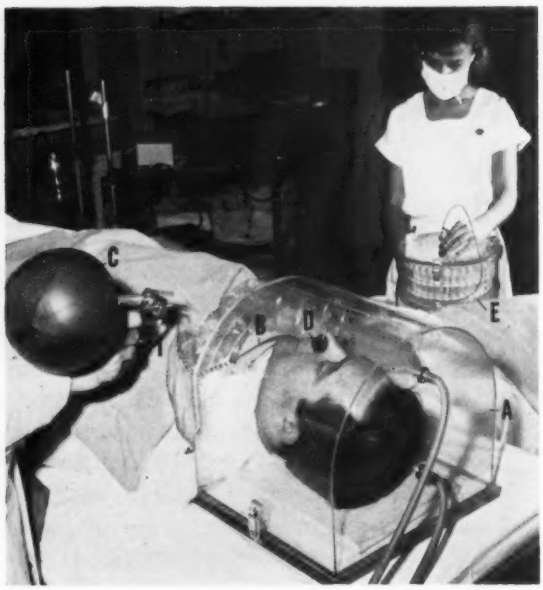

FIG. 3. Apparatus for the isotope dilution technique: acryllic hood (A), rubber catheter (B), air inflated rubber balloon (C) attached to steel tubing (I), nose clamp (D), and cardiac catheter attached to automatic sampling device (E).

this small filter together with the steel tubing is counted in order to determine the exact loss of methyl iodide 131. For the actual examination (Fig. 3), a small rubber catheter (B) and an air inflated rubber balloon (C) are attached to the steel tubing (I) containing the radioactive gas. The patient's nose is closed with a small clamp (D), and the rubber catheter is placed into the patient's mouth. The cardiac catheter is attached to the automatic sampling device (E).* The patient is instructed to exhale and then to take one deep breath. At the beginning of the inhalation the valve on the steel tubing is opened by the operator and the air in the rubber balloon forces the small amount of radioactive methyl iodide gas into the patient's mouth as a "bolus." In children the valve is triggered automatically. Simultaneously with the inhalation the sampling device is started, and blood samples are drawn into test tubes at two second intervals. The rate of blood flow into the test tubes can be regulated by changing the vacuum in the sampling chamber. Usually 10 to 15 samples of 0.3–1.0 cc. of blood are withdrawn. The test tubes are taken out and two or three representative samples are scanned in the scintillation counter for fifteen seconds. If one of the early samples shows high radioactivity, the presence of a left to right shunt is immediately established.

For complete calculation each blood sample is counted for one to two minutes and corrections are made for catheter volume and slight difference in volume of the samples. The curves are standardized to an injected dose of 6,000 counts per 1 meter of surface area. The advantage of this standardization is that all venous return curves have an almost identical height with shunt curves being much higher. The magnitude of a left to right shunt can be immediately estimated by inspection of the shunt curve. For exact quantification of the shunt flow, the area under the curve is calculated.

RESULTS

One hundred and five patients with congenital heart disease who were undergoing cardiac catheterization have been examined by this method at the University of Minnesota Heart Hospital. There was generally good correlation between the oximetric findings and the methyl iodide 131 study in large left to right circulatory shunts. There was excellent correlation between the clinical impression and the methyl iodide 131 test. In 13 patients a shunt was detected by this test in spite of normal oxygen values obtained by the oximeter and VanSlyke method. The clinical diagnoses and findings of the methyl iodide 131 test are summarized in Table II.

It is apparent that the majority of the cases in which oximetry failed had small interventricular septal defects. The excellent correlation between the clinical diagnoses and the findings of the methyl iodide 131 test indicates that the stethoscope of an experienced clinician is a sensitive tool for

* The possibility of drawing one sample manually during the first ten seconds is being investigated.

TABLE II

COMPARISON OF DIAGNOSTIC RESULTS

Case No.	Using Oxygen	Clinical Diagnosis	Using Methyl Iodide 131
1	No shunt	Interventricular septal defect	Interventricular septal defect
2	No shunt	Interventricular septal defect	Interventricular septal defect
3	No shunt	Interventricular septal defect plus pulmonary stenosis	Interventricular septal defect
4	No shunt	Interventricular septal defect	Interventricular septal defect
5	No shunt	Interventricular septal defect? patent ductus arteriosus? interatrial septal defect	Interatrial septal defect
6	No shunt	Interventricular septal defect	Interventricular septal defect
7	No shunt	Pulmonary stenosis or interventricular septal defect plus pulmonary stenosis	Left to right shunt (curve from pulmonary artery only)
8	No shunt	Interventricular septal defect	Interventricular septal defect
9	No shunt	Interventricular septal defect plus pulmonary stenosis, interatrial septal defect?	Interventricular septal defect
10	No shunt	Interventricular septal defect? interatrial septal defect, innocent?	Interventricular septal defect
11	No shunt	Interventricular septal defect	Interventricular septal defect
12	No shunt	Postoperative tetrad	Interventricular septal defect
13	No shunt	Postoperative interventricular septal defect	Interventricular septal defect

detecting ventricular septal defects. Prior to the development of this test, the clinical diagnosis could not be confirmed, and the patients were thought to have functional murmurs. In two postoperative patients, small residual shunts were detected. This is a rare occurrence, since the vast majority of our postoperative patients show complete closure of defects with no residual left to right shunt when examined by this sensitive method. None of the 13 patients with an established diagnosis of a shunt has as yet been operated upon. In Case no. 3 the left ventricle was entered during cardiac catheterization and the presence of interventricular septal defect was definitely confirmed.

There were 2 instances in which the methyl iodide test failed, and a small left to right shunt was detected only by oximetry. Both cases were patients with high pressure interventricular septal defects with a right to left shunt, so-called Eisenmenger's complex. In 1 patient the methyl iodide 131 curve was recorded only from the low right ventricle, which may explain the negative test. No satisfactory explanation can be given in the other case. There were 2 patients with Eisenmenger's complex with no left to right shunts as determined by the oximeter or by the methyl iodide 131 test. The correct diagnosis was established by selective right and left ventriculography.[1] Both cases had decreased pulmonary flow demonstrated on roentgenograms and were throught to have valvular pulmonic stenosis from a study of the roentgenographic findings.

COMMENTS

Basically, two principles are being used to detect small left to right shunts: (1) the arteriovenous difference of an inhaled gas (oxygen, nitrous oxide, krypton 85); and (2) the dye dilution principle with injection of the indicator into the left heart and sampling from the right heart.

In the most widely used oxygen test, the arteriovenous difference is continuously achieved through oxygen consumption by the tissue. Since the oxygen metabolism varies from organ to organ and from individual to individual, the venous blood oxygen levels are not uniform. The use of an inert gas other than oxygen (nitrous oxide or krypton 85) has the advantage of achieving the arteriovenous difference by simple physical solution of gas in body

tissue. The gas content in the caval blood is, therefore, more uniform. The arteriovenous difference is not constant but gradually decreases as the tissue becomes more saturated by the continuous inhalation of gas. Therefore, comparative blood samples must be drawn simultaneously from a systemic artery and the right heart. A certain time must elapse until the body tissue is sufficiently desaturated before a test can be repeated.

The dye dilution principle should yield fewer inconclusive results, since in the presence of a left to right shunt the indicator arrives in the right heart before the venous return. The methyl iodide 131 test is based on the dye dilution principle while using an indicator with a large arteriovenous difference. This combination results in: (1) increased sensitivity with high shunt and low venous return curves. Early venous return from the coronary sinus is, therefore, not a differential diagnostic problem; and (2) a stable body background after forty seconds allowing immediate repetition of the test.

SUMMARY

1. A simple isotope dilution technique is described for detecting left to right circulatory shunts. This technique is especially helpful in cases of small shunts.

2. A tracer dose of radioactive methyl iodide 131 gas is given during one single inhalation, and blood samples are drawn through a cardiac catheter from the right heart.

3. The obtained blood samples are counted in a well scintillation counter, and the results are plotted as a curve which assumes a characteristic form in the presence of a left to right shunt.

4. A shunt can be diagnosed almost immediately by counting some of the samples for a few seconds.

5. Quantification of a shunt is possible without sampling from a peripheral artery.

6. The test is believed to be safe for patient and operating personnel.

7. One hundred and five patients have been examined by this method at the University of Minnesota Heart Hospital. In 13 cases a circulatory left to right shunt was detected by this method in spite of normal oxygen values.

Kurt Amplatz, M.D.
Department of Radiology
University of Minnesota
Medical School
Minneapolis 14, Minnesota

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Vol. 85, No. 6

THE METHYL IODIDE TEST IN LEFT TO RIGHT SHUNTS*

TECHNICAL CONSIDERATIONS

By KURT AMPLATZ, M.D., JAMES F. MARVIN PH.D.,† MERLE K. LOKEN, PH.D., *and* WILLIAM D. MILLER, B.S.
MINNEAPOLIS, MINNESOTA

THE method of detecting small left to right shunts by inhalation of a tracer dose of radioactive methyl iodide has proved to be simple and reliable in a large group of patients. The clinical aspects of this test have been described previously.[1] It is the purpose of this paper to outline some of the technical details which have made it possible to administer this gas safely to several hundred patients.

PREPARATION OF RADIOACTIVE METHYL IODIDE

Radioactive methyl iodide was used for inhalation radiocardiography by Thode and co-workers.[2] These authors described the physical properties of methyl iodide, devised a method of preparing the radioactive gas, and proved its extremely low toxicity. We have developed a simpler way of preparing this gas without the necessity of ether extraction.

Ten mc of radioactive sodium iodide and 20 cc. of distilled water are introduced into an empty 100 cc. glass bottle. One to three drops of stable methyl iodide are added, and the bottle is closed with a rubber stopper. The container is put aside and stored behind lead bricks in a hood.

After 12 to 24 hours the mixture is in equilibrium and radioactive methyl iodide gas can be drawn off by means of a syringe. With a needle, 1 cc. of air is injected through the rubber stopper into the glass bottle and then aspirated. This small amount of air-radioactive gas mixture has approximately 15 to 20 μc of activity. Obviously, the activity in the gaseous state decreases according to the normal decay rate of iodine 131. Therefore, on successive days slightly more gas has to be aspirated in order to retain the same degree of radioactivity. After 3 to 4 weeks the original activity can be restored by adding 7 to 10 mc of sodium iodide to the same bottle.

PROPERTIES OF METHYL IODIDE

Methyl iodide is a yellow liquid with a boiling point of 42.5 C. It is slightly soluble in water (1.4 gm. per liter at 25 degrees)[1] and highly soluble in fats, rubber, plastics, lubricants, etc. This high lipoid solubility is desirable for absorption in the lung but increases the difficulty of handling and administering this gas to the patient.

During early experiments the gas was sealed off in glass tubes and, in order to free it, both ends of the glass tubing had to be broken. Since this proved to be technically difficult and unreliable, stainless steel containers sealed with double valves were developed (Fig. 1). The two stopcocks at the ends of the steel tubing can be closed and opened simultaneously by turning a handle (A). Because conventional stopcock lubricants were found to trap the methyl iodide quantitatively, it was necessary to use silicone 200 fluid* with a viscosity of one million centistokes. This substance did not trap a significant quantity of radioactive methyl iodide and at the same time proved to be an excellent valve lubricant. Prior to the introduction of the gas into the tubing all traces of fat must be removed with a solvent such as carbon tetra-

* Dow Corning.

* This work was supported by a grant of the Minnesota Heart Association.
† Deceased.

FIG. 1. Apparatus for drawing off radioactive methyl iodide and sealing it in a container of stainless steel tubing. Handle A closes and opens simultaneously the two stop cocks at the ends of the steel tubing.

chloride. The radioactive gas can then be drawn up into the container by attaching a syringe as shown in Figure 1.

ADMINISTRATION OF GAS TO PATIENTS

In adults it is satisfactory to administer the gas manually through a rubber tubing. A ureteral catheter is introduced through the nostril into the posterior nasopharynx or it is simply placed on the patient's tongue. The catheter is attached to one end of the stainless steel tubing and an air inflated rubber balloon to the other end. The patient is instructed to exhale. At the beginning of inhalation the valves are opened, and the radioactive gas is flushed with air from the balloon into the patient's air passage.

This simple procedure proved satisfactory for adult patients, but failure in children prompted the development of an automatic injecting device (Fig. 2). In this latter procedure a rubber mask is held over the patient's mouth (A). A flutter valve in the mask indicates the phase of respiration by means of an electric pilot light (B). During expiration an electric contact is closed manually and at the beginning of inspiration the valves of the stainless steel tubing (C) are opened automatically. The radioactive gas is flushed by air from a 50 cc. syringe (D) through the attached tubing into the rubber mask. This device proved extremely valuable in the pediatric age group, allowing administration of radioactive gas to infants. Following one single inhalation the mask is removed from the patient's mouth in order to prevent any rebreathing of methyl iodide.

PROTECTION OF PERSONNEL

No inhalation procedure is entirely foolproof nor does the patient always absorb the total amount of radioactivity; therefore, measures must be taken to prevent air contamination. The patient's head is placed in a constantly evacuated plastic hood for 1 to 2 minutes following the inhalation (Fig. 3). The exchanged air is drawn with a suction pump through a small charcoal filter* (A) which quantitatively traps

* Activated carbon, grade 12×20, Atlas Powder Company, Wilmington, Delaware.

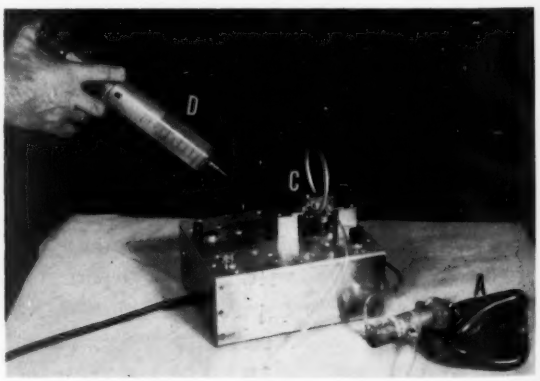

FIG. 2. Equipment for administering radioactive methyl iodide to children. A—rubber mask with flutter valve, B—pilot light to indicate phase of respiration, C—valves of the stainless steel tubing containing the gas, D—syringe containing air.

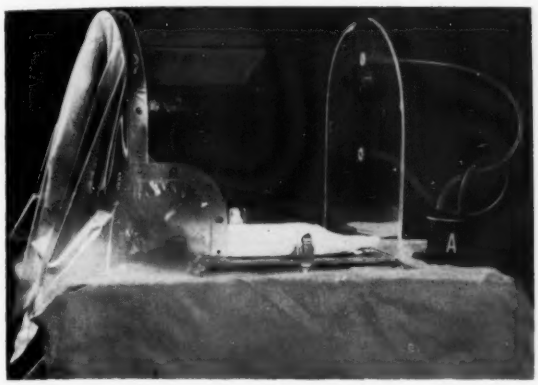

Fig. 3. Plastic hood into which the patient breathes following the inhalation of radioactive methyl iodide. A—charcoal filter which traps exhaled methyl iodide.

methyl iodide. By counting the radioactivity in this filter and the residue in the steel tubing, it is possible to determine exactly the amount of radioactivity absorbed by the patient.

SAMPLING DEVICE

The small tracer doses used (5–8 μc per inhalation) make it impossible to record the radioactivity continuously by drawing the blood through a scintillation counter. A simple sampling device was developed in order to obtain interrupted blood samples, which can be counted in a well type scintillation counter. The sampler consists of a turntable holding 30 test tubes which are enclosed in a plastic housing (Fig. 4). A synchronous motor rotates the turntable at a constant speed allowing sampling at two second intervals. The catheter is attached to the stopcock (A) and the blood stream from the catheter is diverted into separate test tubes through small plastic funnels. In order to obtain adequate blood samples from cardiac chambers with low pressure, *i.e.*, the right atrium and venae cavae, a controllable negative pressure is created in the sampler by a suction pump. No significant radioactivity is lost from the blood samples, despite this vacuum, because of ionization of methyl iodide upon absorption by the patient. The blood samples (usually 10 to 15) range from 0.6 to 1 cc. per sample and are counted in a scintillation counter for 1 to 2 minutes. For immediate results it is adequate to count the first few samples for 15 seconds.

FATE OF METHYL IODIDE IN THE HUMAN BODY

It has been known for a long time that methyl iodide and also ethyl iodide are ionized in the human body. Iodide ions are taken up and stored in the thyroid gland. This property of ionization is of extreme importance to the safety of the personnel. Following the absorption of methyl iodide, its excretion through the lung does not follow the physical laws of partial pressure as do the inert gases. This property of methyl iodide provides a margin of safety and permits the use of this gas in a catheterization laboratory which is not aggressively

Fig. 4. Apparatus for obtaining interrupted blood samples. A—stopcock on a catheter for diverting the blood stream into different test tubes.

ventilated. It is adequate to keep the patient for one minute under the plastic hood, since no significant excretion of radioactive gas is demonstrable via the lung after this time. If the thyroid gland has been blocked with stable iodine prior to the study, almost all of the radioactivity can be recovered in the urine.

Excretion of methyl iodide in the exhaled air and in the urine are shown in Table 1. The patient represented here exhaled forcefully three times through an activated charcoal filter. As can be seen, there is only a small amount of the absorbed activity exhaled after a few minutes. Allowing for normal dilution in room air this amount is considered negligible. On the other hand, 75 to 94 per cent of the administered dose can be recovered in the urine after 36 hours. The biologic half life is approximately 6 hours.

The thyroid gland of the attending personnel acts as an excellent filter, accumulating practically all of the radioactive iodide ions in the air. Thyroid counts at weekly intervals of personnel working in the area have shown no demonstrable radioactivity except on one occasion when a steel tube was opened accidentally. In this instance a small quantity of activity was demonstrable in the thyroid gland of each person who had been in the catheterization room at that time. No attempt was made to flush this material from the thyroid glands of these individuals because of the small amounts involved, and within four weeks no significant activity remained.

On several occasions the room air in the laboratory was drawn through an activated carbon filter for several hours. No radioactivity was found in this filter, indicating the efficacy of the described safety factors. Several hundred patients have now been studied in this same room with no problem of contamination.

TABLE I

METHYL IODIDE EXCRETION*

In Exhaled Air†	In Urine‡
1 min. 1.51%	6 hours 50%
2 min. 0.28%	12 hours 75%
5 min. 0.29%	24 hours 87%
20 min. 0	36 hours 94%

* 14% was not absorbed
† 3 exhalations
‡ Total excretion

SUMMARY

The radioactive methyl iodide test is considered to be a simple, dependable and highly sensitive means for detection of small left to right shunts. Technical details on the preparation and safe handling of this gas are given.

Kurt Amplatz, M.D.
Department of Radiology
University of Minnesota
Medical School
Mineapolis 14, Minnesota

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ANATOMIC DIAGNOSIS OF ATRIAL SEPTAL DEFECTS*

By ERIK CARLSSON, M.D.
ST. LOUIS, MISSOURI

AN ATRIAL septal defect is discovered at cardiac catheterization by a left to right shunt on the atrial level. The mere passage of the catheter through the septum is of only limited diagnostic value because an open but guarded foramen ovale will also permit the catheter to pass through the septum. A left to right shunt on the atrial level is not a decisive sign of an atrial septal defect; abnormal pulmonary venous drainage will also manifest itself by a left to right shunt at the atrial level at cardiac catheterization. Ventricular septal defects with left to right shunts on the ventricular level combined with some tricuspid regurgitation will show increased oxygenation of the blood in the right atrium, simulating an atrial septal defect. The problem is further complicated by the fact that a large number of atrial septal defects show the maximal increase in oxygenation of the blood in the right ventricle and not in the right atrium. The diagnosis of an atrial septal defect by cardiac catheterization alone, therefore, offers difficulties; these are multiplied if one attempts to establish the specific type of the defect. Attempts have been made to determine the anatomic type of an atrial septal defect from the position of the catheter passing through it. Considering the wide range of variation in position and size of atrial septal defects and the necessity to recognize small anatomic structures, cardiac catheterization alone must be considered a rather gross method.

Electrocardiographic examination of the patient has been of considerable value in the differentiation between atrial septal defects of the primum type and atrial septal defects of the secundum type. It has been shown repeatedly, however, that the left axis deviation with incomplete right bundle branch block which is characteristic of primum defects is not constantly present. These changes may also be found in cases of atrial septal defects of the secundum type.[3]

An angiocardiographic method has been described by Kjellberg *et al.*[3] in 1955. It consists of introducing a side hole catheter with a closed end from the saphenous vein into the left atrium through the atrial septal defect. The contrast medium is injected under high pressure. A series of exposures is made at six to twelve seconds. The patient is placed in the right posterior oblique position in relation to the horizontal film. With this method, a picture of the anatomy of the atrial septum is obtained, which permits localization of the atrial septal defect as well as determination of its type and size.

METHOD OF EXAMINATION

We have used the technique of Kjellberg *et al.* described above with some modifications in the position of the patient, the contrast medium, and the screens. In the majority of our examinations the patient has been placed in the right anterior oblique position in relation to the horizontal film (Fig. 1). In this position the interatrial septum will be approximately horizontal, with the left atrium above it. Because of this, the contrast medium that is injected into the left atrium can pass into the right atrium more quickly, thus enhancing the possibility of exposing films before the left ventricle becomes opacified, masking the lower part of the atrial septum. The horizontal beam is centered on the vertical film changer with the patient in the right posterior oblique position in relation to that

* From the Edward Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri.
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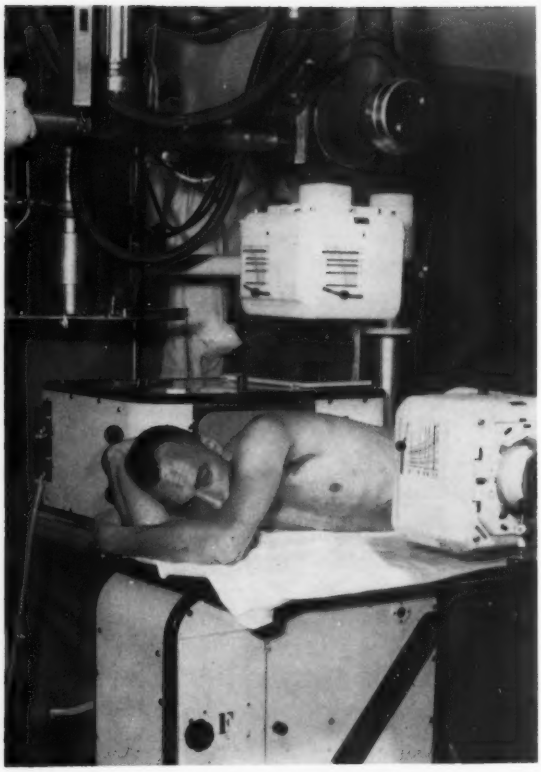

FIG. 1. Positioning of the patient for angiocardiographic study of atrial septal defects. Exposures in the right anterior oblique and the right posterior oblique projections are made. The interatrial septum is approximately in the horizontal plane with the left atrium above the right atrium.

changer (Fig. 1). Sodium diacetamidotriiodobenzoate (hypaque) in a concentration of 50–75 per cent has been used instead of sodium acetamidotriiodobenzoate (urokon) in 70 per cent solution and has given satisfactory contrast density. Urokon 70 per cent was employed only in a few early cases.

We have also utilized high sensitivity, thallium activated potassium iodide screens and high output tubes. These two factors permit exposure at lower kilovoltage than is possible with ordinary screens and tubes. The lower energy radiation allows better visualization of diluted contrast media.[1]

COMPLICATIONS

No reactions to the main injection of the contrast material have occurred, except in 2 patients in whom urokon 70 per cent was used. Severe headache for approximately fifteen minutes and vomiting was observed in these patients. In 4 cases, 3–5 ml. of 50 per cent hypaque, given as a test dose, caused characteristic changes in the electrocardiogram with bradycardia, S-T elevation and absence of the T-waves (Fig. 2). Decreased systemic arterial pressure, cold sweat and dizziness were noted. The reaction started immediately after the injection of the test dose and it lasted for approximately fifteen minutes. The main injection was not performed in these cases as the cause of the reaction was not clear. Although allergic reaction to the contrast medium was the possible mechanism, accidental air injection or the mechanical effect of the catheter could not be excluded.

CLASSIFICATION OF ATRIAL SEPTAL DEFECTS

Atrial septal defects are generally classified into the following groups: (1) common atrium, (2) foramen ovale defects, (3) sinus venosus defects, and (4) ostium primum defects.[2,3,4]

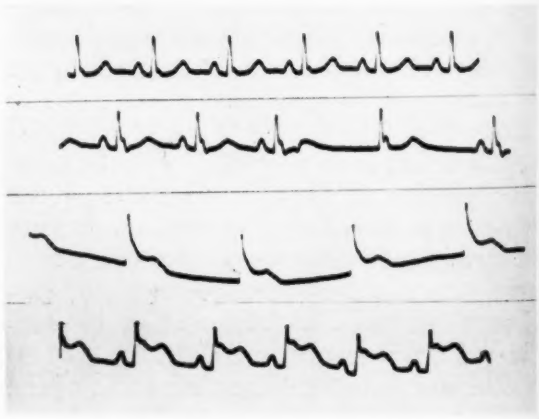

FIG. 2. Electrocardiogram of a thirty-three year old female with atrial septal defect before injection and recording the reaction during injection of a small test dose of hypaque 50 per cent (4 ml.) into the left atrium. Bradycardia, S-T elevation and absence of the P-waves are noted. The reaction started immediately after the injection of the contrast medium and lasted for fifteen minutes, after which a normal electrocardiogram was obtained.

In a case of a common atrium the septum is absent; small ridges may persist, however, indicating embryologic rests of the septum.

The foramen ovale defects arise either because of a developmental arrest of the septum secundum or because of over-resorption of the septum primum. Two types are observed; in one the defect is confined to the fossa ovalis area, and in the other the defect extends toward the inferior vena cava so that there is no lower margin of the defect above the orifice of this vessel.

Sinus venosus defects are situated above the fossa ovalis. The uppermost portion of the septum is absent in the region of the defect. The pulmonary vein from the right upper lobe is connected to the superior vena cava at its opening into the right atrium.

Ostium primum defects are situated in the lower part of the septum and the lower margin of the septum defect is formed by the upper edge of the ventricular septum. Transitional forms between this type of atrial septal defect and a common atrioventricular canal occur. The mitral and tricuspid valves are involved in varying degrees.

ROENTGEN FINDINGS

Informative films are obtained in the plane which is perpendicular to the interatrial septum (the right posterior oblique projection). From these films the cephalocaudal diameter of the defect and the distance of the defect from the upper part of the interventricular septum may be evaluated to some extent. From the films in the other plane (the right anterior oblique projection), however, only a rough estimate of the position of the catheter during the injection can be made if the catheter enters

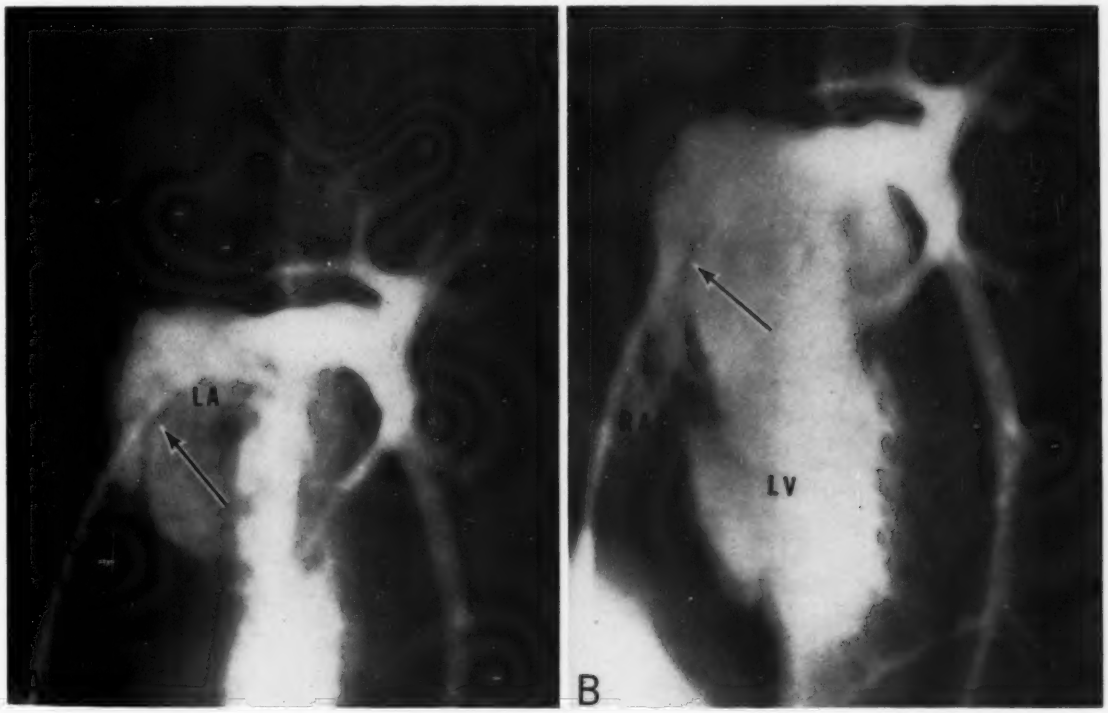

Fig. 3. (*A* and *B*) A four year old boy with an open foramen ovale but no atrial septal defects. Two leaflets forming the interatrial septum are clearly seen. The arrow shows the septum primum and the catheter is seen to pass between it and the septum secundum. A small amount of contrast medium enters the right atrium, probably because the catheter keeps the leaflets of the spetum apart. No increase in the oxygenation of the blood in the right atrium could be demonstrated at cardiac catheterization. LA—left atrium, RA—right atrium, LV—left ventricle, C—catheter.

FIG. 4. A twenty-six year old male with an atrial septal defect of moderate size of the foramen ovale type. The remainder of the atrial septum below the defect is marked by the arrow. The size and position of the defect can readily be evaluated. (The findings were verified at operation.) LA—left atrium, RA—right atrium.

the left atrium through the defect. Some conclusions concerning the position of the defect in the ventrodorsal direction may be arrived at if the defect is of moderate or small size. In other cases the possibility of determining the position of the defect in ventrodorsal direction is rather limited. Figure 3, *A* and *B* shows the roentgen appearance of an open guarded foramen ovale with the two leaflets forming the atrial septum in the region of the fossa ovalis. The catheter has been passed between the septum primum and the septum secundum into the left atrium. A small leak of contrast medium around the catheter is present, probably because the catheter separates the two septa. No left to right shunt was demonstrated by cardiac catheterization.

The size and position of a foramen ovale defect of moderate size can readily be evaluated if the stream of contrast medium from the left atrium to the right atrium through the defect is strong and well defined (Fig. 4). If for some reason the stream of contrast medium is less defined, the size and the position of the defect cannot be judged. The atrial septum is sometimes demonstrated (Fig. 5) as a thin structure rising from the upper edge of the ventricular septum. If this angiocardiographic finding is combined with the typical clinical findings, the diagnosis of a secundum defect is highly probable.

If the position of the defect is undeter-

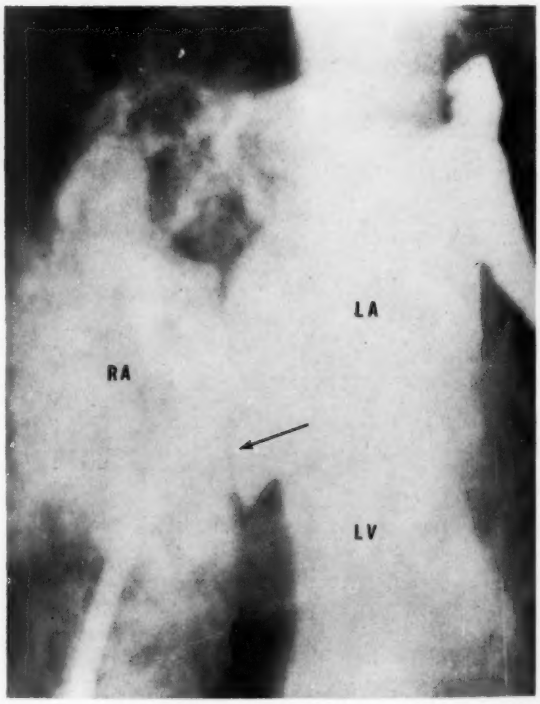

FIG. 5. An atrial septal defect of the foramen ovale type in a twelve year old female. The remainder of the atrial septum below the defect is marked by an arrow. The size of the defect cannot be evaluated. (The diagnosis was verified at operation.) RA—right atrium, LA—left atrium, LV—left ventricle.

mined in the ventrodorsal direction, it is impossible to establish reliably from the angiocardiograms in the right angle plane projection whether the defect is close to or far from the upper edge of the interventricular septum. The differentiation between a primum and a dorsally placed secundum defect may, therefore, be impossible (Fig. 6). In Figure 7, *A* and *B* a primum defect of moderate size is shown. In this case the catheter did not pass

Fig. 6. An atrial septal defect in a forty year old male (operatively verified to be of the inferior vena cava type). The defect is large and is situated low in the interatrial septum. Filling of the veins of the liver and the inferior vena cava was seen in the right anterior oblique projection. Differentiation between this type of atrial septal defect and a large primum defect is difficult.

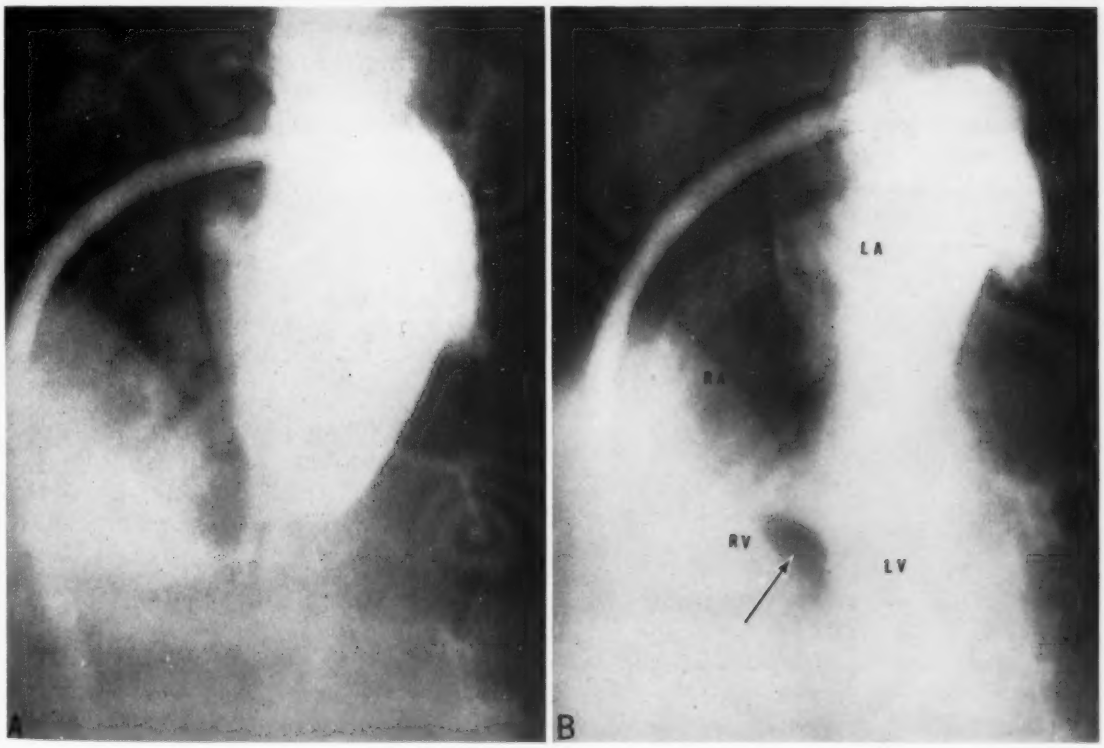

Fig. 7. (*A* and *B*) An atrial septal defect of the primum type in an eight year old female. The catheter passes from the right atrium to the left atrium via an open foramen ovale high in the septum. The defect low in the septum is marked with an arrow. (Verified at operation.) RA—right atrium, LA—left atrium, RV—right ventricle, LV—left ventricle.

through the defect but through an open foramen ovale to the left atrium. This case illustrates the difficulty in diagnosing the type of defect from the position of the catheter alone.

In a case of common atrium, the contrast medium is seen to pass freely from the left atrium to the right atrium without any signs of an interatrial septum (Fig. 8, *A* and *B*).

A sinus venosus defect is shown in Figure 9, *A* and *B*. The defect is located high in the atrial septum. No remnant of the septum forming the cephalad margin of the defect can be seen.

RESULTS

A total of 75 interatrial septal defects diagnosed at Barnes Hospital between January, 1958 and July, 1960 is discussed in this paper. In 53 cases the diagnosis was established at surgery under direct vision. Among these, 38 were foramen ovale type defects, 5 were inferior vena cava type defects, and 10 were septum primum type defects.

Angiocardiography with injection into the left atrium has been done in 54 cases and the following diagnoses were made: moderate sized foramen ovale type defects, 38 cases; septum primum defects, 4 cases; large, low defects which cannot be differentiated from a septum primum defect, 6 cases; sinus venosus defect, 2 cases; open foramen ovale, 1 case; technical failure, 3 cases. Of these 54 cases, 29 were operated. One of the cases diagnosed as a secundum defect had, in addition, a septum primum defect which was found at operation. (This case is counted as a septum primum defect in the classification of the total material.) Both defects were repaired within the time limit imposed by hypothermia. Five of the 6 cases of large low atrial septal defects were found at operation to be inferior vena cava type defects. The exception was a typical foramen ovale type defect.

Twenty-four of the above mentioned 53 cases were operated without the prior aid of angiocardiography and, in some instances, even without cardiac catheterization. In this group unexpected septum primum defects were discovered at operation under hypothermia in 3 instances. The

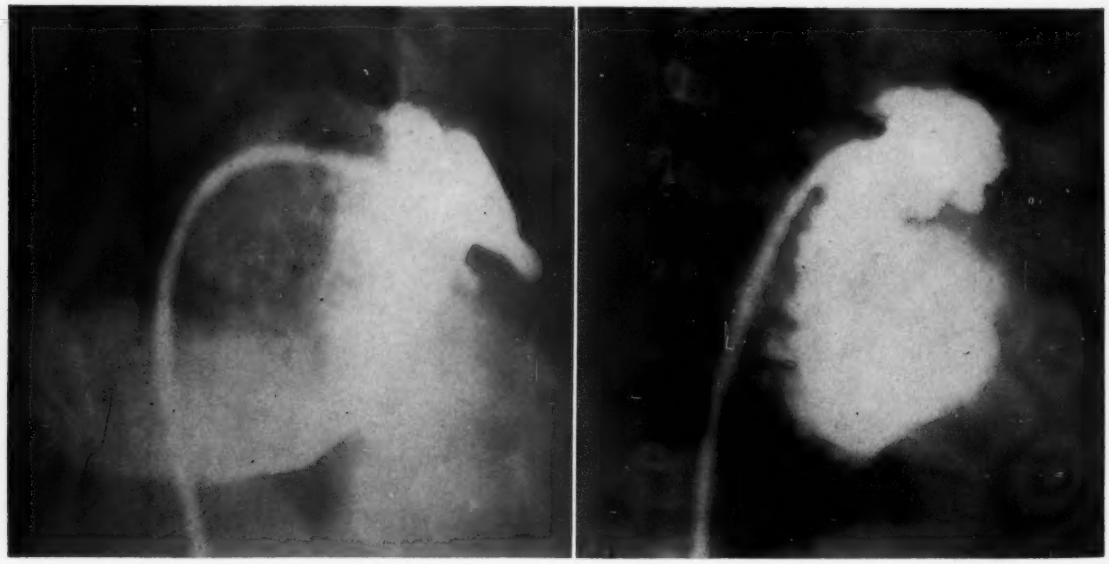

FIG. 8. (*A* and *B*) Common atrium in a six year old male. The contrast medium passes freely from the injection point in the left part of the atrium to the right side without any sign of an interatrial septum. The catheter is probably in contact with the cephalad atrial wall. (Not operated.)

Fig. 9. (*A* and *B*) Sinus venosus defect in a twenty-five year old male. The defect is seen in the upper part of the interatrial septum (arrow). No remnant of a septum cephalad to the defect is seen. (Not operated.) RA—right atrium, LA—left atrium.

operation could not be completed in 2 of the cases; the third patient succumbed, partly because of the incomplete diagnosis. In another case, angiocardiography was done with injection into the right ventricle and a primum defect was diagnosed as a ventricular septal defect. In this case an unnecessary ventriculotomy was performed because of the wrong diagnosis. Two primum defects were correctly diagnosed or suspected and the patients were operated upon using extracorporeal circulation. Eighteen typical secundum defects were correctly diagnosed in this group.

The classification of the total material, diagnosed either at the time of operation or by angiocardiography, is as follows:

Secundum defects of the foramen ovale type	56
Secundum defects of the inferior vena cava type	5
Sinus venosus defects	2
Common atrium	1
Primum defects	11

In all but 1 of the primum defects a left axis deviation with an incomplete right bundle branch block was found on the electrocardiogram. In 2 cases the atrial septal defects of the secundum type were combined with abnormal pulmonary venous drainage. One case of a secundum defect was combined with an interventricular septal defect. We did not include in this report the cases with a combination of atrial septal defect and pulmonary stenosis. In cases of that type we prefer to perform the injection into the right ventricle. An anatomic diagnosis of the atrial septal defects was not established in these instances.

CONCLUSIONS

Atrial septal defects are operated upon either under hypothermia or with the help of extracorporeal circulation. The surgical approach under hypothermia is safe, simple and economical and is preferred in cases of uncomplicated foramen ovale defects. Some surgeons operate, however, upon all atrial septal defects using extracorporeal circulation because of the difficulty in obtaining a reliable preoperative diagnosis. They refuse to take the risk of finding an unsuspected,

complicated lesion and not having sufficient time for its repair.

From an analysis of our case material it is obvious that the diagnostic procedure for the preoperative diagnosis of atrial septal defects needs further improvement. It is also clear, however, that the diagnostic reliability increases when angiocardiography is added to the other diagnostic procedures. The analysis shows also that a very large proportion of the foramen ovale defects can be recognized before operation and that the risk of missing complicated lesions is small.

SUMMARY

A total of 75 cases of atrial septal defects is discussed. In 53 cases an operation has been performed and the diagnosis was established under direct vision; 24 of these cases did not have prior angiocardiography, which was performed in 54 cases. Angiocardiography improves the preoperative diagnostic accuracy and permits a safe selection of cases for operation under hypothermia.

Thorax Kliniken
Karolinska Sjukhuset
Stockholm 60, Sweden

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LOW VISCOSITY CONTRAST MEDIA FOR CARDIOVASCULAR VISUALIZATION*

By CHARLES T. DOTTER, M.D., *and* KURT R. STRAUBE, M.D.
PORTLAND, OREGON

NOT only can Robb and Steinberg[15] be credited with the technique for visualization of the intrathoracic circulation but it was also they who, by simply boiling down the then available (35 per cent) dilute diodrast, obtained a contrast agent of required higher opacity and, through use, determined the concentration (70 per cent) and dosage of that drug which, for years, remained standard for intravenous angiography.

Contrast agents for today's selective cardiovascular visualization techniques share the basic requirements of adequate opacity, low toxicity and ease of injection.[3] Widespread use of techniques involving the injection of these agents through catheters has further increased the importance of the latter characteristic.

In a systematic scrutiny of the flow rates of several angiocardiographic media, Cooley[2] has emphasized the variations in ease of injection among different preparations at different temperatures. Expressing the dose rate as grams of iodine (delivered) per second, he concluded that about 12 gm. of iodine per second was a minimum acceptable delivery rate. He noted that it was necessary to warm miokon 90 per cent if the room temperature delivery rates of lower viscosity urokon sodium 70 per cent were to be equaled.

For conventional intravenous angiocardiography, the dose ranges, in general, between 0.3 and 0.5 cc./lb. body weight and must be delivered within a period of one and one half seconds. When made through large bore needles and syringes into distensible veins, this dose rate can usually be accomplished manually. Such, however, is usually *not* the case when catheters are employed to deliver the injected bolus to a specific central location. Despite the fact that selective injections (because of reduced dilution by blood) generally require a smaller dose to provide equivalent opacity at a given site, the frictional resistance offered by a small catheter usually makes necessary the use of a high pressure mechanical injection device. The Shipps Automatic Injector[17] is a reasonably priced and very satisfactory instrument for this purpose. Thin-walled nylon catheters,[9,12,16] special radiopaque plastic catheters,[11] and simple polyethylene tubing[13] all possess definite advantages over the standard Cournand intracardiac catheter in terms of the dose-delivery rate. Of these, polyethylene seems preferable for several reasons. Our techniques for percutaneous venous and arterial catheterization do not permit (or require) the use of radiopaque nylon cardiac catheters.[4] We employ a method of guided percutaneous femoro-aortic left ventricular catheterization using nonradiopaque polyethylene tubing.[5,14]

Regardless of the catheter or special injecting device employed, the viscosity of the agent represents an important determinant in the ease with which a given injection may be accomplished. Other things being equal, low viscosity media are desirable because they are more readily injected, do not as frequently require the use of special pressure apparatus, rarely are associated with the necessity for repeat injections due to tubing or injection apparatus failure, may be handled at room temperature, and, when they permit manual injection, are less apt to result in serious extra-

* From the Department of Radiology, University of Oregon Medical School, Portland 1, Oregon. The Minthorn Laboratory for Cardiovascular Research through Radiology.
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TABLE I

PROPERTIES OF FIVE HIGH IODINE CONTRAST AGENTS

	Ditriokon	Hypaque M 75 Per Cent	Hypaque M 90 Per Cent	Cardiografin	Urokon Sodium 70 Per Cent
Manufacturer	Mallinckrodt Chemical Works, St. Louis 7, Mo.	Winthrop Laboratories, New York 18, N. Y.	Winthrop Laboratories, New York 18, N. Y.	E. R. Squibb and Sons, New York 22, N. Y.	Mallinckrodt Chemical Works, St. Louis 7, Mo.
Chemical Nature	31.4 per cent sodium diprotrizoate (miokon sodium) and 36.7 per cent sodium diatrizoate (hypaque sodium) in water solution; a mixture	25 per cent sodium diatrizoate and 50 per cent N-methyl glucamine diatrizoate (two salts of hypaque) in water solution; a mixture	30 per cent sodium diatrizoate and 60 per cent N-methyl glucamine diatrizoate (two salts of hypaque) in water solution; a mixture	85 per cent watery solution of N-methyl glucamine salt of diatrizoic acid (hypaque); monomolecular	70 per cent water solution of the sodium salt of acetrizoic acid (urokon sodium); monomolecular
Relative Viscosity (in CPS with H_2O as unity)	25° C. 8.7 37.5° C. 7.0	37.5° C. 11.0	25° C. 46.8 37.5° C. 30.3	25° C. 28.8 37.5° C. 23.3	25° C. 7.2 37.5° C. 6.1
Iodine Content	40 per cent w/v	38.3 per cent w/v	46 per cent w/v	40 per cent w/v	46 per cent w/v
Supplied	Commercially available in 50 cc. bottles; clear, moderately viscid solution	Commercially available in 50 cc. bottles; clear, watery solution	Commercially available in 50 cc. bottles; slightly viscid solution about half full of white precipitate at room temperature; clears on warming	Commercially available in 50 cc. bottles; clear, moderately viscid solution	Commercially available in 25 cc. ampules; clear, watery solution
LD 50 mg./kg. in mice (manufacturer's figures)	10,700	12,600 ± 877	12,600 ± 877	10,500	8,000 to 11,200

vasation. Thus they contribute to the ease, speed and safety of cardiovascular contrast visualization.

Ditriokon and hypaque M 75 per cent appear to offer improvement over several currently employed media with respect to the balance between viscosity and iodine content.*

COMPARISON OF PROPERTIES OF FIVE CONTRAST AGENTS

Pertinent chemical, physical and pharmacologic properties of ditriokon and hypaque M 75 per cent are compared with those of cardiografin, urokon sodium 70 per cent and hypaque M 90 per cent in Table I.

Viscosity Studies. Using the Swank-Roth method,[18] the viscosities, at 37.5°C., of fluid contrast media of various chemical compositions and concentrations were determined and are shown in Table II. The concentrated preparations commonly employed for contrast cardiovascular visualization were subjected to further studies in order to relate viscosity, temperature, concentration, and iodine content. Data obtained are presented in Figure 1. It is apparent that very significant differences in viscosity exist.

DITRIOKON

Since ditriokon is a combination of two drugs which have been widely employed as intravenous contrast media in man, extensive preclinical testing was not considered necessary. (Manufacturers' LD 50's are compared in Table 1.) The myocardial effects of several contrast substances were studied by means of occlusion aortography, a procedure which affords precise means for the injection of predetermined quantities of drugs into the coronary arteries of intact subjects.[6] So tested, ditriokon produced electrocardiographic alterations in excess of those seen with corresponding doses of current commercially available media for cardiovascular visualization. The dog's electrocardiogram is not necessarily indicative of man's pharmacologic response to the clinical administration of these or any drugs.

CLINICAL APPLICATION

At the University of Oregon Medical School Hospital, ditriokon has been injected 277 times in the course of 133 examinations performed on 126 patients (March 10, 1959 through June 1, 1960) referred for various cardiovascular visualization pro-

* Renovist (Squibb), a similar low viscosity agent, was not available at the time of this study. We have used it subsequently and found it a satisfactory preparation for the purposes under consideration.

TABLE II

VISCOSITY OF SEVERAL CONTRAST AGENTS SUITABLE FOR INTRAVASCULAR USE*

Contrast Agent	Viscosity	Per Cent Iodine w/v
Miokon 30 per cent	1.8	17
Diodrast 35 per cent	1.9	18
Renografin 30 per cent	1.95	15
Hypaque Sodium 50 per cent	3.1	30
Urokon Sodium 70 per cent	5.8	46
Ditriokon	7.5	40
Renografin 59.7 per cent	10.9	29
Hypaque M 75 per cent	11.0	38.5
Renografin 76 per cent	11.7	37
Thorotrast 24–26 per cent	15.0	none
Cardiografin	23.3	40
Hypaque M 90 per cent	25.8	46
Miokon M 90 per cent	32.3	46

* As determined by the Swank-Roth technique[18] at 37.5° C. with water as unity. Contrast agents arranged in order of increasing viscosity. Iodine contents from manufacturer's description.

cedures not including cerebral angiography. In over half of these cases the indication for examination was congenital cardiovascular disease; the remaining were studied for various reasons, including acquired cardiopulmonary disease and conditions affecting the aorta, its major branches and the peripheral blood vessels. The patients' ages ranged from ten days to seventy-nine years. In 25 children (19.6 per cent of the 126 patients) a general anesthetic was given.

DOSE AND ROUTE OF ADMINISTRATION: ROENTGENOGRAPHIC CONTRAST

The dose of ditriokon was related to the method of study and, generally speaking, was comparable to that used for other concentrated contrast media. The volume of injections ranged from 4 cc. to 50 cc. Young children were usually given one or more injections consisting of 1 cc. of ditriokon for every two pounds of body weight. The usual examination required two or three injections (71 and 54 times, respectively). One adult patient was given four 30 cc. injections and another four 50 cc. injections of ditriokon, each within one half hour and without evident ill effect. A breakdown by site of injection follows:

Intravenous	68
Right atrium	6
Right ventricle	19
Left atrium	2
Left ventricle	64
Proximal aorta	46
Aortic arch and branches	17
Abdominal arch and branches	53
Other (spleen)	2

The roentgenographic contrast was adequate and often excellent (Fig. 2–6).

COMPLICATIONS

During the course of this study there occurred 1 death, that of a two year old child weighing twenty pounds and afflicted with Fallot's tetralogy. The study, done under general anesthesia, involved three intravenous injections of ditriokon (10 cc., 10 cc., and 8 cc.). Neither the conduct nor course of the examination appeared unusual and at its conclusion the child was taken to the recovery room. Forty to fifty minutes later, asystole was noted and re-

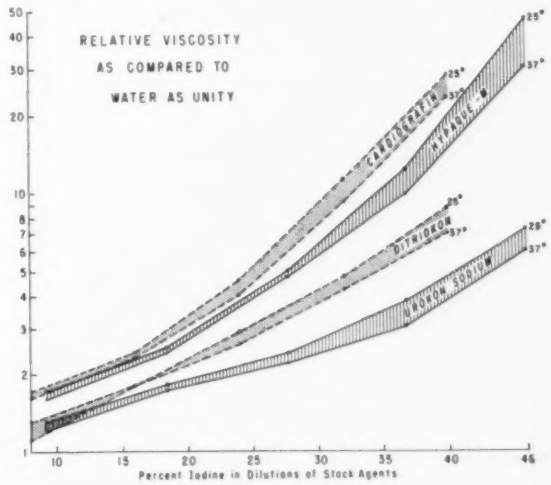

FIG. 1. *Graph of viscosity-iodine content curves for urokon sodium, ditriokon, cardiografin and hypaque M.* Viscosity (in CPS relative to water as unity) is shown at room temperature (25°C.) and at body temperature. Plotted in terms of injection pressure or rate, rather than viscosity, and concentration or opacity, rather than iodine content, the information presented in these crucial curves would be the same. The basic relationship between viscosity and opacity is a linear, apparently exponential, function.

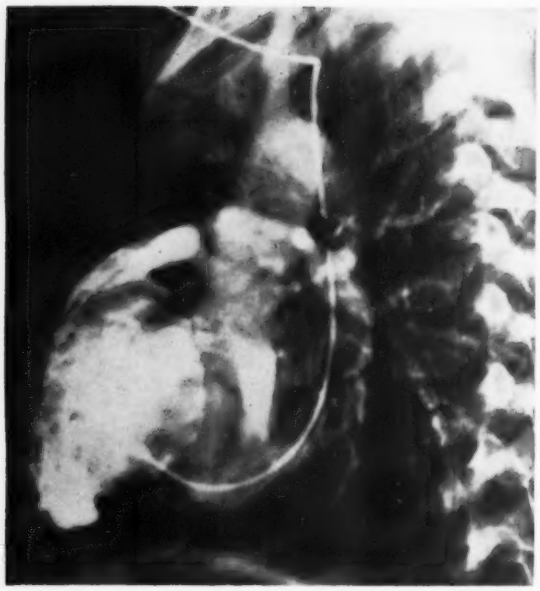

FIG. 2. *Tetralogy of Fallot.* Selective right ventriculogram of a six year old boy (UOMS #22-58-31). Ditriokon (25 cc.) was manually injected. Overriding aorta, normal pulmonary valves and hypertrophic right ventricular outflow tract narrowing are demonstrated. The findings were subsequently confirmed at corrective open heart surgery.

suscitation was attempted at an undetermined period after its onset. This failed. Autopsy confirmed the anatomic diagnosis but shed no light on the mechanism of death.*

Cardiac arrest also developed in a six year old boy who weighed forty pounds and who was believed to have corrected transposition of the great blood vessels. Following percutaneous femoral catheterization, done with the patient under general anesthesia, an initial injection of 12 cc. of ditriokon was made into the left atrium. Approximately ten minutes thereafter, a second injection of 17 cc. of ditriokon was made into the left ventricle. About fifteen minutes later, tachycardia and declining left ventricular pressure appeared and within two to three minues led to cardiac arrest.

* In the experience of one of the writers, which includes 4,500 major cardiovascular contrast visualizations, death has occurred five times, nonfatal cardiac arrest twice. That these seven catastrophes were not all due to the (several) contrast agents involved is strongly suggested by the fact that all but one occurred in patients subjected to general anesthesia. It does not of necessity follow that general anesthesia constitutes the major hazard of angiography.

Continuously recorded blood pressures through the catheter allowed the accurate timing of the events which followed. Fifty-three seconds after the onset of asystole, thoracotomy was begun and five seconds later the first pressure pulse due to manual massage was recorded. Three minutes and twenty-eight seconds thereafter, the welcome appearance of a surgeon in the doorway was overshadowed by the simultaneous, presumably otherwise unrelated, return of a normal heartbeat. Recovery was prompt, complete and free of complications despite a bare-handed thoracotomy.

Parenthetically, once asystole or ventricular fibrillation appears, artificial respiration is as important as cardiac resusci-

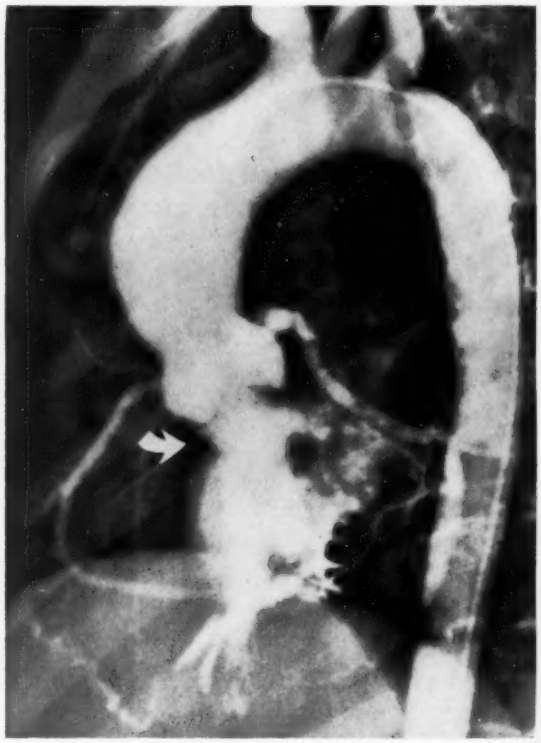

FIG. 3. *Subaortic stenosis.* Left ventriculogram of a nine year old girl (UOMS #22-04-31). Ditriokon (30 cc.) was injected following percutaneous femoral arterial catheterization done under local anesthesia. The arrow points to localized indentation of the left ventricular outflow tract below the normal aortic valves. The pressure studies and subsequent corrective open heart surgery were confirmatory. The coronary vessels are normal. We have used ditriokon to demonstrate severe coronary disease in man.[1]

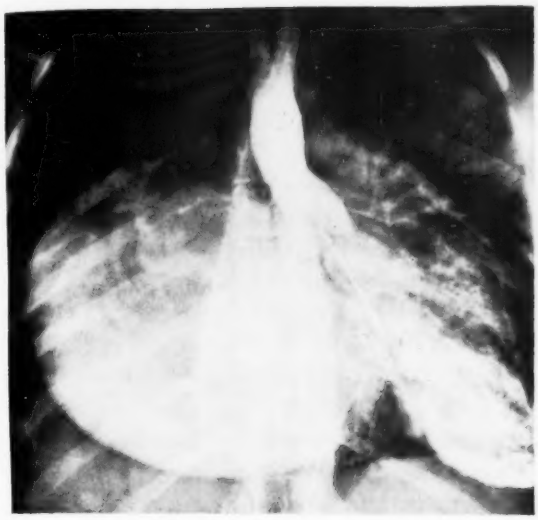

Fig. 4. *Mitral insufficiency and marked dilatation of left atrium.* Left ventriculography percutaneously performed in a thirty-two year old female with rheumatic heart disease (UOMS #25-28-01). Ditriokon (45 cc.) was injected (Shipps injector) during one second into the left ventricle. The film shows marked regurgitation of contrast agent into massively dilated left atrium.

tation. By virtue of the attendant delay in establishing coronary blood flow, the initial use of external defibrillators has probably already caused death. Closed chest cardiac resuscitation[19] has in our hands proved superior to direct cardiac massage in the management of such emergencies.[20] *A normal heart beat will not be obtained in the presence of continuing myocardial anoxia, whether due to asystole, ventricular fibrillation or inadequate respiratory exchange.* Mouth-to-mouth artificial respiration should be employed when needed.

There were no other serious complications. Within a matter of hours after percutaneous left ventriculography, 3 patients developed generalized petechial rashes, unaccompanied by fever or other untoward consequences and regressing spontaneously during the ensuing twenty-four to forty-eight hours. Elaborate studies of blood coagulation mechanisms in 1 of these cases failed to reveal any abnormality. While it is impossible to exonerate the contrast substance, other possible causes include toxicity due to incompletely rinsed off sterilizing solutions and embolization due either to imperfect heparinization or to the inadvertent injection of minute droplets of air during the left-sided injections, which were performed on all 3 patients.

During the course of this study, the electrocardiogram was often observed during the clinical administration of ditriokon. The most commonly encountered alterations included T-wave flattening, coving and inversion, S-T segmental depressions of varying degree and moderate sinus tachycardia. All were of brief duration and seemed directly related to the intensity of myocardial exposure to the drug. Such changes have repeatedly been shown to occur following the administration of commercially available angiocardiographic media.[7,8,10] They bear absolutely no relation to the nonoxygen bearing nature of the injected fluids but, rather, are expressions of myocardial response to pharmacologically active drugs.

This report includes the observation that in dogs the myocardial response to ditriokon is more severe than that observed with urokon or hypaque. That this is not a contraindication to the general use of ditri-

Fig. 5. *Carcinoma of uterine cervix.* Percutaneous pelvic arteriogram in a thirty-four year old woman (UOMS #27-35-59). Ditriokon (25 cc.) was manually injected at aortic bifurcation during blood pressure cuff occlusion of both femoral arteries. The uterine arteries are clearly shown. Location of a tumor mass at left fornix is suggested by the vascular pattern. Start-to-finish time of entire procedure was less than eight minutes.

okon is supported by data supplied by the manufacturer to the effect that a dozen other workers have injected ditriokon 662 times in 463 examinations. Many of these injections were made into the left heart or proximal aorta. The general impression of those using it appeared to be that ditriokon offered no greater risk in frequency and severity of side effects than commonly used agents.

While questioning the advisability of direct intracoronary or cerebral administration of ditriokon, we regard it as a satisfactory and, with respect to viscosity, a superior general purpose medium for other forms of contrast cardiovascular visualization.

SIDE EFFECTS: SUBJECTIVE REACTIONS

A detailed discussion of the difficulties in evaluating the subjective effects of new cardiovascular contrast media is included in the initial report on the use of urokon for angiocardiography.[3] It is reasonable to suspect that the manufacturer's gift of investigational samples of a new and presumably improved drug subjects the investigator to an unconsciously favorable bias. Everyone likes to be first to bring good news! Although double-blind methods of

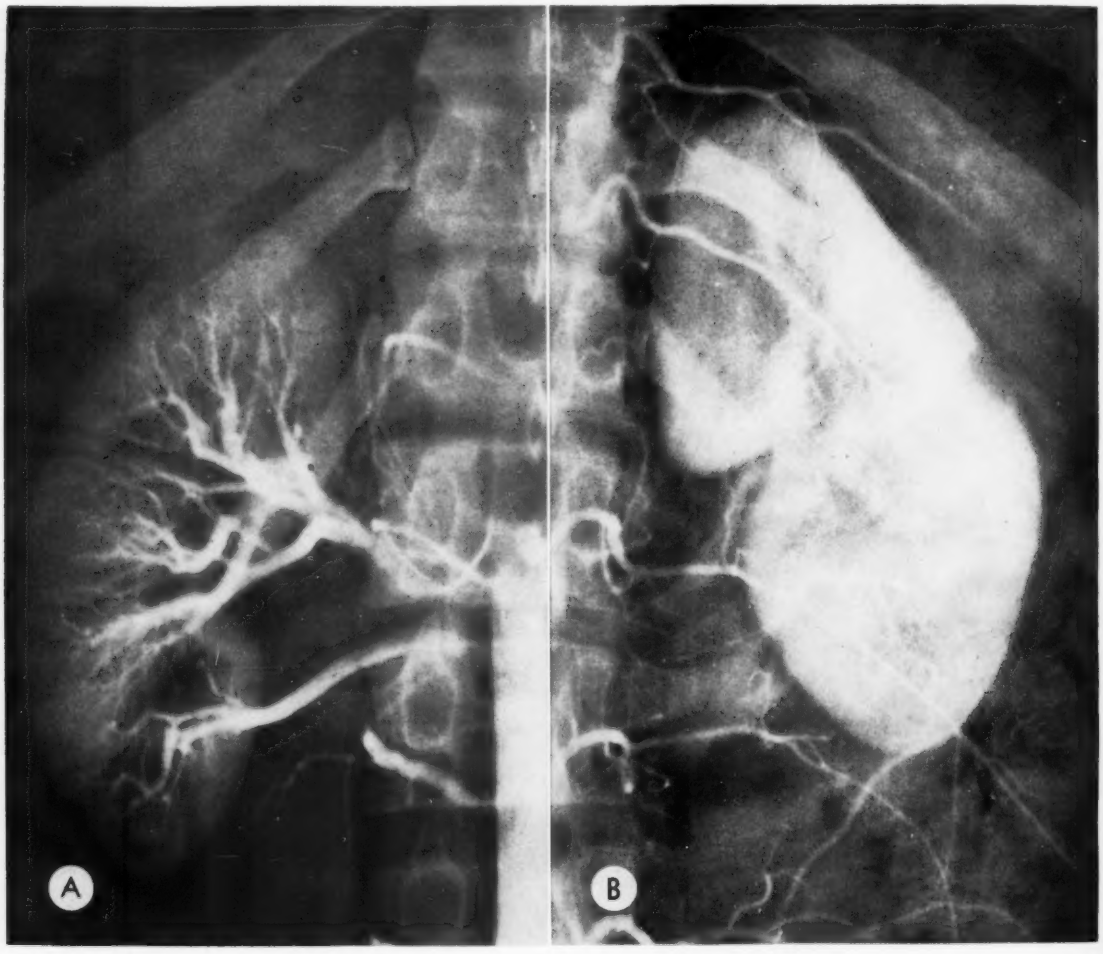

FIG. 6. *Left renal cyst.* Percutaneous renal arteriograms in a forty-five year old man with hypertension (UOMS #27-58-44). Ditriokon (35 cc.) was injected at the level of the renal arteries. (*A*) Normal right renal arteries are shown at one and one half seconds after a one second injection. (*B*) Left nephrogram five seconds after injection clearly reveals a 1 cm. subcortical cyst. This procedure is easier, faster and more informative than nephrotomography.

evaluation will significantly reduce this possibility of bias, important clinical and economic considerations oppose their use in the initial trials of new substances for contrast visualization. Bearing this in mind, we are, nevertheless, of the opinion that, in terms of minor side effects and subjective reactions, ditriokon approaches hypaque and cardiografin in desirability and is probably superior to roentgenographically ideal urokon.

Our records were not kept with sufficient consistency to warrant the optimistic "statistical" conclusion seemingly indicated by a very low incidence of recorded side effects. Of the 126 patients receiving ditriokon, 27 (all children) were anesthetized. Our anesthesiologists noted no unusual manifestations attributable to the drug. Specific questions concerning the subjective reactions were directed at some but not all of the patients who were examined under local anesthesia. It was evident that a sensation usually described as heat or flushing was a constant feature. A transient wave of nausea was experienced fairly frequently, though vomiting occurred in only 3 patients.

In evaluating the significance of the foregoing, it should be borne in mind that many of the examinations involved the direct and rapid injection of massive doses of the contrast agent into the left ventricle or proximal aorta, thus minimizing their dilution and producing maximum systemic, cerebral and coronary (if not pulmonary) responses. Preliminary clinical data appear to indicate that the subjective response to ditriokon will prove to be roughly comparable to that of other preparations already in widespread use.

HYPAQUE M 75 PER CENT

Twelve injections (from 10 to 50 cc.) of hypaque M 75 per cent were made in the course of angiographic studies on 7 patients. This limited experience permits only a brief comment.

Despite the fact that hypaque is higher in viscosity and lower in iodine content than ditriokon, the differences are likely to prove insignificant in terms of injectability and resulting radiopacity, while subjective side effects seem somewhat milder with hypaque M 75 per cent. The difference, if it exists, is not pronounced. The LD 50 will provide the only means for comparing toxicity until further clinical experience has been gained with both agents.

DISCUSSION AND EXTRAPOLATION

The synergistic enhancement of desirable common properties combined with the reduction or cancellation of undesirable properties represents a useful pharmacologic approach which has numerous counterparts in man's formal experience and way of life. Current techniques for cardiovascular visualization require contrast agents of high radiopacity, low viscosity and minimum toxicity. Ditriokon and hypaque M 75 per

Fig. 7. Percutaneous retrograde aortogram demonstrates hypertensive elongation and tortuosity of innominate, subclavian and carotid arteries with anomalous origin of left common carotid from innominate artery in a sixty-seven year old female (UOMS #28-19-93). Two injections of hypaque M 75 per cent (35 cc. each). Clinically, a pulsating mass has been present in the base of the neck on the right side.

cent are the water solutions of materials having different molecular structures. While their radiopacity reflects the total amount of iodine in solution, their viscosity is lower than could be obtained through comparably opaque solutions of their constituent molecules, *e.g.*, the solubility of hypaque and miokon sodium is so low that concentrations equivalent to ditriokon in iodine content tend to crystallize at room temperature. This explains why the concentrated preparations of hypaque and miokon have only been available as mixed solutions of two different salts of the respective parent molecules.

Fluid viscosity (unlike that of gases) is inversely related to temperature and is determined by the physical interrelationships of component molecules. Thus, the mixture of two fluids, even in the absence of a chemical combination, can result in a solution of significantly lowered viscosity. In ditriokon the use of different molecules and in hypaque M 75 per cent the use of different salts of the same basic molecule have led to a significant reduction in viscosity (concentration and total dose of each agent) without a corresponding sacrifice of opacity.

Laboratory studies of dose-delivery curves under the conditions of use serve to confirm the wisdom of fixing the iodine content of ditriokon and hypaque M 75 per cent at levels somewhat lower than heretofore thought optimal. It is apparent that the manufacturers elected to avoid the steeper part of the viscosity-opacity curve, which occurs at higher concentrations. In both instances deliberate efforts were made to provide contrast agents featuring an optimal relationship between viscosity and opacity, the optimum being determined by the necessity for the rapid injections demanded by current techniques. On the basis of preliminary clinical observations, we believe the efforts to have been successful.

It is tempting to speculate upon the possibilities of mixing radiopaque agents for cardiovascular visualization. The relatively low incidence of side effects observed during this study leads to the fascinating thought that there might be a combination of several radiopaque compounds (probably, though not necessarily, iodine-containing) which would provide very high opacity, low viscosity and hitherto unobtainably low toxicity. It is evident that the side effects, subjective reactions and, perhaps, even the serious complications attendant upon the use of today's contrast media are, to some extent, dose-dependent. It is also entirely possible that, though similar in character, these undesirable properties are in fact pharmacologically distinctive and nonadditive. If so, it follows that *pharmacologically subthreshold doses of these drugs could, in combination, provide adequate radiopacity without causing appreciable side effects or even a recognizable subjective response to angiocardiographic injections!* Accumulating experience indicates that any of the various contrast media now in use are apt to be associated with occasional fatalities during contrast visualization. The responsible mechanisms are not clear but apparently are not due to allergic or immunologic sensitivity in the usual sense of the terms. While it is, of course, possible that such a multicomponent agent might reduce minor toxic effects and at the same time increase the hazard of use by a factor equal to the number of drugs used, it is also possible that both serious and minor toxic effects could be reduced to the point of negligibility.

CONCLUSIONS

1. Desirable cardiovascular contrast agents reflect a functional compromise between viscosity and opacity.

2. Ditriokon has been used for the examination of 126 patients with heart disease, and its qualities have been clinically evaluated.

(a) Ditriokon, a new contrast agent for cardiovascular visualization, is a water solution containing 36.7 per cent w/v diatrizoate sodium (hypaque) and 31.4 per cent w/v diprotrizoate (miokon) in a mixture providing 40 per cent organically bound iodine (0.4 gm./ml.).

(b) Our laboratory studies reveal that ditriokon has a significantly lower viscosity and is, therefore, correspondingly easier to inject than other commercially available concentrated contrast media except urokon sodium 70 per cent.

(c) Initial clinical application, using various routes of injection, suggests that it approaches the effectiveness of hypaque M 90 per cent and cardiografin and is superior to urokon sodium 70 per cent in terms of reducing subjective reactions and minor side effects produced by rapid, massive injections into the cardiovascular system.

3. Hypaque M 75 per cent is a less concentrated preparation of hypaque M 90 per cent, a double salt mixture now on the market in 90 per cent strength. Although of slightly lower iodine content and higher viscosity than ditriokon, hypaque M 75 per cent is of relatively low toxicity and satisfies the requirements for a low viscosity contrast medium.

4. The present study suggests the possibility that a decided further improvement in cardiovascular contrast agents may be sought in multicomponent media wherein radiopacity is increased while undesirable pharmacologic properties are reduced to negligible proportions through antisynergistic or simple divisive effects. While in medicine "shotgun" techniques often earn just criticism, their occasional superiority is certainly not limited to duck hunting.

Charles T. Dotter, M.D.
University of Oregon Medical School
Portland, Oregon

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DITRIOKON:* A NEW ANGIOCARDIOGRAPHIC MEDIUM

By S. S. SANDERSON, M.D., *and* K. E. GROSS, M.D.†
TACOMA, WASHINGTON

A NEW contrast medium, ditriokon, has recently been introduced for use in angiocardiography. It is a high-contrast, low-viscosity solution of 68.1 per cent solids, 36.7 per cent ditrizoate sodium and 31.4 per cent diprotrizoate sodium, providing 0.4 gm. I/cc. Its viscosity is 5.5 cps at body temperature.[18] This is lower than other contrast media now on the market with the exception of urokon sodium 70 per cent. This is not the first use of mixtures of opaque media. Massell and co-workers[14] in 1957 reported less toxicity and better opacification by a 2:1 mixture of methylglucamine and sodium salts of diatrizoate in peripheral angiography and aortography. Ditriokon represents a new concept in contrast media to the extent that it is a combination of two entirely different compounds as opposed to products which are merely mixtures of different salts of the same basic compound.

The present study is not an attempt to compare the relative merits of various opaque media, but rather to report on the use of this particular medium and to present some of our observations. Of primary interest was the performance of ditriokon in selective angiocardiography during routine catheterizations as recorded by cineroentgenography at 30 frames per second on 16 mm. movie film using a Picker 8 inch amplifilmer. A few conventional angiocardiograms and arteriograms were made with a Schönander biplane film changer. All rapid injections were performed with a Gidlund high pressure injection syringe which warms the contrast material to body temperature. The types of procedures used are shown in Table 1.

CLINICAL MATERIAL

Ditriokon was used in 75 patients for a total of 146 injections. The patients ranged in age from five months to fifty-one years. More than half, 38, were less than eight years old; 18 were eight to thirteen years old; 19 were fifteen to fifty-one years old. There were 39 females and 36 males. One to five injections per patient were given. The largest dose 45 cc., was used in a 243 pound male. A dose of 40 cc. was given a 100 pound, twelve year old female. An 88 pound child received five injections totaling 55 cc. in a period of forty-five minutes. In none of these were any unusual reactions noted.

METHOD

Satisfactory visualization of the right side of the heart and the pulmonary artery under most circumstances is not difficult. Filling of the left heart and aorta from a right-sided injection so that a definitive diagnosis can be made is more difficult. This is especially true in smaller children in whom it is impossible to introduce a catheter larger than a size 5 into the pulmonary artery. Delivery of high-iodine content opaque materials through small catheters is very slow. Opaque medium dribbling from the catheter results in intermittent filling of the pulmonary arteries long after the left side has filled. Under such circumstances, neopacification of the right side of the heart and the pulmonary artery is usually obscured. The smaller catheter may be withdrawn after samples and pressures have been obtained, and a larger one inserted for angiocardiography. This prolongs the examination, increases

* Manufactured by Mallinckrodt Chemical Works, St. Louis, Missouri, which supplied the ditriokon used in this study and the technical data concerning it.

† From the Department of Radiology, Mary Bridge Children's Hospital, Tacoma, Washington.

TABLE I

TYPE OF PROCEDURES

	Patients	Catheterizations	Injections	Recorded by		Pulmonary Wedge Injections	Catheter Size				Needle No. 15
				Cineroentgenography	Schönander Changer		4	5	6	7	
Selective Cardioangiography	69	71	136	94	4	38	1	88	46	1	—
Conventional Angiography and Arteriography	6	—	10	2	8	—	—	3	3	2	2

the radiation exposure and risk, and does not solve the original catheter placement problem. The lower viscosity of ditriokon does improve the flow rate and at least reduces this problem.

Cineroentgenography was used to record 94 of the 136 selective angiographies. Routine cine-exposure consisted of a two second burst before injection. A ten second exposure was made after the left ventricle was empty. A total exposure of twenty to thirty seconds resulted. By counting the frames of the finished movie strip, very accurate catheter emptying times may be obtained. Figure 1 shows a comparison of the flow rates of 71 injections and the trial results when 4 new, size 5 Cournand "smooth bore" catheters* were used. These figures reveal a wide range in flow rates for catheters of the same size, a difference in some instances of more than 300 per cent. The primary reason for this is the varying catheter bore. The present "smooth bore" Cournand catheters are more uniform than older types of end-opening catheters; however, considerable variation still exists as seen in Figure 1, line A. Catheter bore may be altered in other ways. Re-ending catheters when the metal connecters break off is poor practice. Tightening the knurled ring sufficiently to produce a tight joint will reduce the bore by 50 per cent or more. Clotting within and around the openings of catheters reduces the effect of the bore. Such clots, attached to the ends of catheters and impregnated with opaque medium, are visible on cineroentgenograms.

The curves in Figure 2 show the flow rates of ditriokon through various catheters. The figures for Cournand "smooth bore" catheters are in excess of corresponding published figures for more viscous media, injected through Lehman[13] catheters at 45° C. Lehman and similar catheters deliver 25 to 100 per cent more medium, the percentage difference being greater in

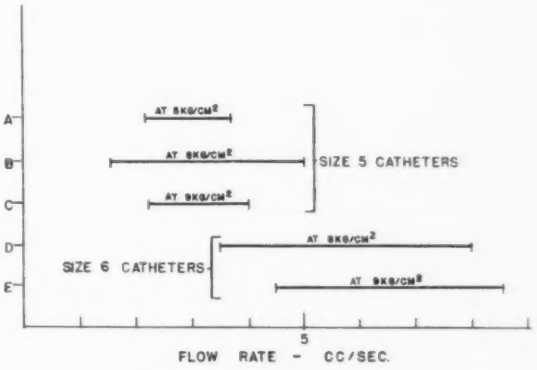

FIG. 1. Diagram showing a comparison of flow rates through different catheters of the same size. A—Test "injections" using 4 new size 5 Cournand "smooth bore" catheters. B—Flow rates in 28 routine angiocardiographies using size 5 catheters. C—Flow rates in 16 routine angiocardiographies using size 5 catheters. D—Flow rates in 12 routine angiocardiographies using size 6 catheters. E—Flow rates in 15 routine angiocardiographies using size 6 catheters.

* Manufactured by the United States Catheter and Instrument Corporation, Glens Falls, New York.

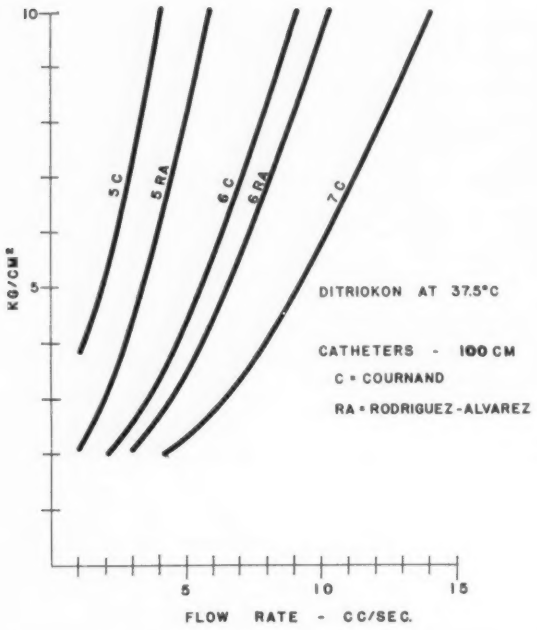

FIG. 2. Flow rates of ditriokon with various catheters at 37.5° C. using 30 cc. for each reading determination.

the smaller sizes. Lehman[13] advocates temperatures above 37.5° C., claiming that no tissue damage has been demonstrated in experimental animals when temperatures as high as 60° C. were used. The improvement in flow rates through increased temperature is greater with thicker media and at lower pressures. Ditriokon, being a medium of lower viscosity, is influenced less by an increase in the temperature at low pressures than a more viscid medium.

Satisfactory visualization may be obtained by the use of 0.2 to 0.3 cc. of ditriokon per pound body weight; in no case should less than 6 cc. be used. Injection is carried out at pressures of 9 to 10 kg./cm.^{2} No catheter has ruptured at these pressures.

RESULTS

Visualization of the cardiac chambers and great vessels was critically studied with particular attention to the left side of the heart and the aorta. In Table II "good visualization" is synonymous with "satisfactory for diagnosis." When flow rates drop below 3.1 cc./sec. and amounts below 0.2 cc./pound, visualization of the left heart is usually poor. Visualization of the aorta is more capricious and seems to follow the rule that the speed of injection is more important than the amount of medium. As little as 0.16 cc./pound of opaque medium resulted in good aortic filling, providing the flow rate was 4.5 cc./sec. or greater. It would appear that as long as the bolus remains relatively intact, the amount injected as well as the injection speed may vary considerably and still result in satisfactory opacification. In large hearts and those with excessive recirculation through large shunts, there is considerable dilution of medium. This, as well as eddy currents causing stagnation of contrast medium in pools at various locations, interferes with diagnosis. Figley[7] has pointed out that delay in opacification of the left heart is often associated with pulmonary stenosis and pulmonary hypertension and, to a lesser degree, with some cases of acquired heart disease. This also may affect visualization in that there is greater opportunity for unopacified blood to mix with the opaque medium.

Thirty-eight injections were made for pulmonary wedge studies and 1.5 to 2.0 cc. of medium was sufficient for good visualization using a size 5 catheter. Originally, the recommendations of Bell and co-workers[2] were followed, using 2.0 to 3.0 cc. of contrast material. There is less tendency to extravasation with the smaller amounts. Bell *et al.* used a size 7 catheter but their reported cases were those of adults, which probably accounts for the use of larger amounts. Injection is carried out manually, 1 cc. fills the catheter; the remainder is injected rapidly when the signal for roentgenographic exposure is given. When the catheter is truly wedged, excellent filling is the rule.

REACTIONS

SYSTEMIC REACTIONS

Ditriokon has proved to be a safe medium. It is composed of chemical compounds which have been used in a great

number of individuals and for many years. Reactions, with few exceptions, have been very mild and transient. Such systemic symptoms and reactions as cough, sneezing, nausea, apprehension, bitter taste in the mouth, a feeling of warmth and flushing are common to all iodine-containing compounds used in roentgenologic examinations. These, only, were encountered. Cough occurred in 13 cases, usually in those having pulmonary artery injections. It was mild in most instances, the patient coughing one to four times. In one, cough initiated gagging, which in turn was followed by retching and laryngospasm. The entire episode lasted less than one minute, and was relieved by the anesthesiologist. One patient sneezed once, 2 complained of nausea, 3 of apprehension, and most of flushing, warmth and/or bitter taste in the mouth. There were no instances of vomiting, urticaria, laryngeal edema or other, more severe, allergic reactions.

CARDIAC ACTION

There is common agreement that cardiac action during catheterization, though no contrast medium is injected, is at times very unstable. A wide variety of irregularities of rate and rhythm in varying degrees of severity and even cardiac arrest have occurred.[1,3,4,12,15,19] Extrasystole, acceleration and slowing of heart rate in various combinations have been noted during almost all catheterization procedures. These same reactions occur in conventional and selective angiocardiography.[1,3,4,6,8,9,11,13,15]

The safety of ditriokon can be substantiated by frame to frame inspection of cineroentgenograms. This method of recording heart action is dramatic. Irregularities are easily seen and heart rates can be counted by a stop watch or by counting frames. An accuracy comparable to that of the electrocardiogram can thus be achieved. In addition to the 79 instances summarized in Table II, 5 additional cineroentgenograms of poorer technical quality proved satisfactory for this purpose. There were 22 cases of extrasystole; a single beat occurred in 6, two to four beats in 9, and the remaining 7 developed a short run, lasting not over three seconds. There were 15 similar short runs of accelerated rate and 4 instances of slowing of heart rate.

Twenty-five of the 75 cases studied showed sufficient instability of cardiac action during catheterization that a note to this effect appears on the record. This is contrasted with 59 "stable" hearts as shown in Table III. Cineroentgenograms showed no change in rate or rhythm during injection in 60 per cent of the "unstable" and 56 per cent of the "stable" hearts.

The following cases illustrate marked degrees of cardiac instability which was essentially unaffected by selective angiocardiography with ditriokon:

Case 1. A prior catheterization was terminated in a female child of six years because of

Table II

QUALITY OF VISUALIZATION

Amount of Ditriokon Injected (cc./pound)	Left Side of Heart						Aorta					
	Flow Rate (cc./sec.)						Flow Rate (cc./sec.)					
	1.6 to 3.0		3.1 to 4.5		over 4.5		1.6 to 3.0		3.1 to 4.5		over 4.5	
	good	poor	good	poor	good	poor	good	poor	good	poor	good	poor
.075–.20	4	8	6	6	6	10	2	10	2	10	6	10
.21–.30	5	4	7	1	6	1	7	7	4	4	7	0
.31 up	8	2	2	0	3	0	3	7	1	1	3	0

intractable bradycardia. The cardiac rate dropped to forty beats per minute following the introduction of a catheter into the pulmonary artery. Six months later, at restudy, 12 cc. (0.24 cc./pound) of ditriokon was injected into the right ventricle with no clinical reaction and no abnormalities seen on cineroentgenograms.

CASE II. Prior catheterization was terminated in this four and one-half year old male child following cardiac arrest which occurred when a catheter was introduced into the pulmonary artery. Thoracotomy was required to initiate cardiac action. Five months later the child was restudied at which time 7 cc. (0.2 cc./pound) of ditriokon was injected into the pulmonary artery with no clinical reaction. There was a moderate increase in heart rate observed on cineroentgenograms.

CASE III. This eight and one-half year old male with transposition of the great vessels and cyanosis received an injection of 12 cc. (0.28 cc./pound) of ditriokon into the right ventricle. Cineroentgenograms showed no cardiac abnormality and there was no clinical reaction.

The following case was the only instance of severe reaction following ditriokon injection. In view of subsequent events at restudy, some doubt can be expressed that the contrast medium was the actual cause of the asystolic period.

CASE IV. This fifteen month old female with a large interventricular septal defect, reversed shunt and occasional cyanosis was catheterized under general anesthesia. Following a 2.5 cc. pulmonary wedge injection, she had an episode of dyspnea and cyanosis. Catheterization was continued after she had stabilized. Twenty minutes later, a second injection of 5 cc. (0.28 cc./pound) of ditriokon into the main pulmonary artery was followed within a minute by a fifteen second period of asystole which terminated during withdrawal of the catheter to the inferior vena cava. Cineroentgenograms showed a single extrasystole followed by tachycardia prior to the asystolic period. Following recovery, the heart rate rose to 210 where it remained for seven minutes and then subsided within the next two to three minutes to the original rate of 120. Three months later, restudy with injection of 6 cc. (0.315 cc./pound) of ditriokon resulted in no clinical reaction. Cineroentgenograms at this time revealed three extrasystoles during injection.

TABLE III

ABNORMALITIES OF CARDIAC ACTION AS NOTED BY CINEROENTGENOGRAPHY

Part Injected	"Stable" Hearts						"Unstable" Hearts					
	No. of Injections	No Reaction	Acceleration of Rate	Extrasystole	Slowing of Rate		No. of Injections	No Reaction	Acceleration of Rate	Extrasystole	Slowing of Rate	
Right Atrium	13	8	3*	3*	0		2	2	0	0	0	
Right Ventricle	10	5	1	4	0		10	6	2	2	0	
Pulmonary Artery	36	20	6†	8	3†		13	7	3‡	5‡	0	
Totals	59	33	10	15	3		25	15	5	7	0	

* In 1 injection both acceleration and extrasystole occurred.
† Initial acceleration decreased near the end of cineroentgenography.
‡ In 2 injections both acceleration and extrasystole occurred.

Two additional cases with extended periods of abnormal cardiac action also deserve mention.

Case v. This eighteen month old male with acyanotic tetralogy of Fallot was noted under general anesthesia to have an unstable heart showing frequent extrasystoles. A pulmonary wedge injection using 1.5 cc. of ditriokon, a pulmonary artery injection using 7 cc. (0.35 cc./pound) of ditriokon and a right atrial injection using 7 cc. of ditriokon were done within a half-hour. Two minutes after the last injection, he developed a long run of extrasystoles which lasted nearly twenty-five minutes before being controlled. Oxygen was administered during this period. Cineroentgenograms revealed no abnormalities in cardiac action during the immediate postinjection period.

Case vi. This five year old female, with a small interatrial septal defect, was noted under local anesthesia aided by hypnosis to have an unstable heart with many extrasystoles and a tendency to develop tachycardia. Within two minutes following injection of 15 cc. (0.25 cc./pound) of ditriokon, she developed tachycardia which lasted four minutes and ceased spontaneously. Cineroentgenograms were not obtained due to improper loading of the camera.

EXTRAVASATION

Extravasation occurred in one pulmonary artery and in three wedge injections. There was cough in each instance. The medium was rapidly absorbed, especially in the wedge injections, and disappeared before the catheterization was terminated. In each case, the cause of the extravasation was too much medium injected under too great a pressure. In the pulmonary artery injection, the catheter was inadvertently advanced into one of the smaller pulmonary arteries of the right upper lobe while turning the patient into the oblique position for cineroentgenography. It is estimated from the cineroentgenograms that about 15 cc. was injected at a pressure of 9 kg./cm.^{2} into the right upper lobe, most of which entered the lower portion of the anterior segment. Pressures before and after injection were 27/10 and 35/18, respectively. An irregular density, 3 by 5 cm. in size, was visualized for about an hour, after which time it decreased in size. In twenty-four hours it had reduced to a small homogeneous linear density less than half the original size. Except for violent coughing initially, there was no other symptom of lung damage and no hemoptysis developed.

BLOOD PRESSURE CHANGES

Systemic blood pressures have been taken routinely before and after catheterizations for more than two years. Variations in most instances are mild and there has been no change in this regard since using ditriokon for angiocardiography.

Many authors have published their observations on the effect of various contrast media on systemic blood pressure.[3,5,8,11,15,16] Graphs illustrate an initial drop in blood pressure of varying degree with most media. The change occurs in some cases immediately and in others within fifteen to twenty seconds following injection. In a few there is a rise in blood pressure. The two components of ditriokon, the sodium salts of ditrizoate and diprotrizoate, have opposing effects on systemic blood pressure at high dosage levels.[15,18] The former produces a mild rise while the latter causes a similar decrease. These changes occur immediately after injection and are stated to be less pronounced than with other contrast materials of different chemical composition.[15,16,18]

Postinjection pressure in cardiac chambers and great vessels has received little attention in the literature. Dotter and coworkers[5] state, "Right atrial pressures did not rise significantly during the rapid 'angiographic' administration of saline to adults." This accompanies a discussion of the dissipation of the tremendous pressures generated in conventional angiography. Bell *et al.*[2] mention taking postinjection pressures in pulmonary wedge injections, but do not give any of their observations. McFall and others[15] injected water, saline and various opaque materials into the hearts and great vessels of dogs in doses of 1.0 to 1.5 cc./kg. at pressures of 600 psi.

They state, "In general, these substances were not distinguishable from one another by the nature of this response." Out of 48 injections, early blood pressure drop occurred in 23.

Similar experiments were carried out by Nordenström,[17] who injected 1 cc./kg. saline and urokon into the inferior vena cava, right auricle and right ventricle of dogs. He reports an increase of 1 to 2 mm. Hg in right atrial pressures. In the right ventricle, pressures increased 20 to 30 per cent for two to seven heart beats after injection. He found that urokon has less effect than saline.

Routine procedure in this study consisted of taking postinjection blood pressures immediately after cineroentgenography. In all cases this was well within one minute after injection. Table IV summarizes 59 injections and shows that in 41, nearly 70 per cent, systolic pressures rose. Later, pressures were obtained in some instances in the same location and showed a return to initial levels.

In the majority of instances, the changes were mild. In the right atrium the systolic pressure in 3 cases rose from 12/0 to 21/6, 7/1 to 13/2, and 14/8 to 20/10, respectively. In 1 case it remained the same at 20/7. The most alarming systolic pressure elevations occurred in the right ventricle. Here, in several cases of high systolic pressure, a significant rise was noted: 110/20 to 130/−5 (Case VI), 80/6 to 115/0, and 110/20 to 115/5 (Case V). Two blood pressures remained at 85/0 and 135/0, respectively. One fell from 140/20 to 125/5 (Case I). In 5 instances there were blood pressures of 50 mm. Hg or more in the pulmonary artery; in 4 of these, elevations occurred, usually 5 to 10 mm. Hg, but in 1 the rise was from 50/16 to 90/58 (Case IV). In 1 case the blood pressure dropped from 50/12 to 37/1. In 1 instance of left ventricular injection, there was a rise from 95/45 to 135/5.

TABLE IV

IN VIVO SYSTOLIC PRESSURE CHANGES WITH INJECTION OF DITRIOKON

Part Injected	No. of Injections	Pressures		
		Increased	Not Changed	Decreased
Right Atrium	9	8	1	0
Right Ventricle	10	5	3	2
Pulmonary Artery	40	28	2	10
Totals	59	41	6	12

It is quite obvious that such blood pressure rises could reverse an already existing shunt and produce, at least momentarily, a lowered oxygen content in the systemic circulation and cyanosis. It is also significant that Cases I, IV, V and VI are in this group. It would appear that when markedly elevated pressures are found in the right ventricle, injection into the right atrium or pulmonary artery is preferable. Blood pressures built up during injection drop immediately to former levels as soon as the injection is terminated.[5]

At the present time one can only speculate on the cause or causes of these blood pressure changes. Are they due to vasoconstriction or vasodilatation of the pulmonary arteries? Is there a direct action on cardiac muscle through coronary artery filling, causing a change in cardiac action? Is it a mechanical effect of the jet impinging on the septum of the heart, causing thereby a change in cardiac contractions? Do any of the systemic reactions, such as apprehension, play a part? Is "sludging" of the blood to blame? Is the type of anesthesia a factor? Does the type of lesion have any significance?

SUMMARY

1. Experience with 146 injections using ditriokon* in angiocardiographic and other vascular studies, especially in selective angiocardiography with cineroentgenography, is discussed.

2. The relatively low viscosity of ditriokon increases the speed of injection.

* Ditriokon also has been used in retrograde and voiding cystography in 56 cases, in 10 choledochographies and in several studies of the fistulous tract. In these cases visualization has been excellent and there have been no reactions.

3. Satisfactory visualization can be obtained with injections of 0.2 to 0.3 cc./pound body weight.

4. Less than half of the patients studied showed any abnormality of cardiac action during or immediately after injection.

5. There is usually a mild rise of blood pressure in the injected part. Markedly elevated initial pressures may prove alarming but in our study no sequelae were noted.

6. Frame by frame inspection of cineroentgenograms is an excellent method of studying heart action before, during and for a short interval after injection.

7. Cardiac catheters produced by the same manufacturer and of equal size do not necessarily deliver like amounts of media per time unit.

8. Ditriokon appears to be an excellent, safe angiocardiographic medium.

S. S. Sanderson, M.D.
522 Medical Arts Building
Tacoma, Washington

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AN INJECTION TIMING DEVICE FOR ANGIOCARDIOGRAPHY

By PAUL SEKELJ, PH.D.E.,* FRED BRENT,† *and* SCOTT DUNBAR, M.D.‡
MONTREAL, QUEBEC, CANADA

WE HAVE developed a method of timing and recording the opaque medium injection during angiocardiography in relation to a continuously recording electrocardiogram.

The method, described below, is simple and appears to be reliable. It permits permanent recording of the time of the beginning and the end of the injection in relation to the electrocardiogram, in addition to the total duration of the injection. Knowing the amount of opaque medium injected, the flow rate can be readily calculated. The electrocardiogram and any arrhythmias can be analyzed in relation to the time and duration of the injection.

The device is an adaptation of the Gidlund compressed air injection syringe. A circuit is opened as the syringe piston begins its travel, and closed as the piston travel is completed. This provides a straight line interruption of a continuously recorded second channel wave tracing on the electrocardiogram (Fig. 1, 2 and 3).

Figure 4 is a diagram of the essential parts of the syringe with the adaptation for timing of the injection. Before the control-release push-button is activated, contact *a* is closed, the recorder circuit is energized through a 6 volt storage battery or through a 6 volt D. C. power supply operated from the mains. The recording

* The Department of Biophysics, The Montreal Children's Hospital.
† Picker X-ray Engineering Ltd., Montreal.
‡ The Department of Radiology, The Montreal Children's Hospital.

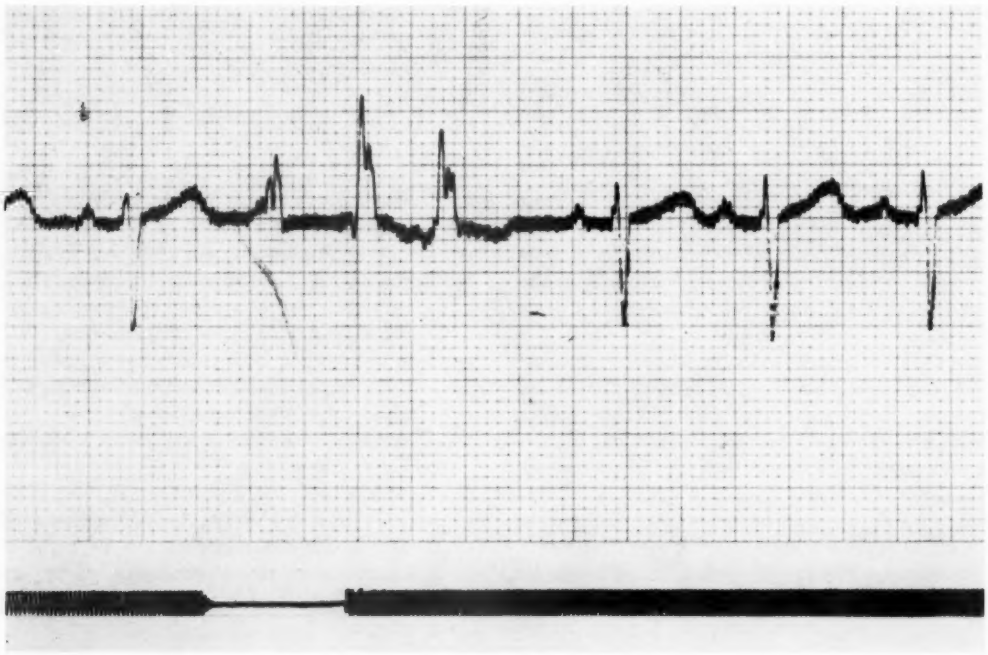

FIG. 1. Nine cubic centimeters of 70 per cent sodium urokon were injected in .45 second through a No. 6 Rodriguez-Alvarez catheter. Three aberrant ventricular complexes occurred during and immediately following injection, with subsequent prompt restoration of normal rhythm.

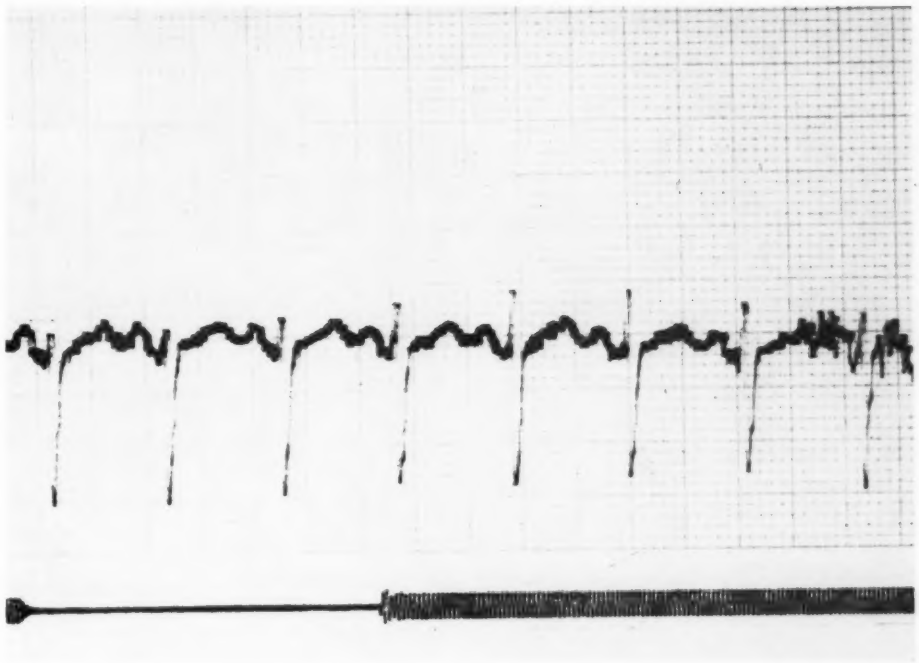

FIG. 2. Eight cubic centimeters of 70 per cent sodium urokon were injected in 1.25 seconds through a No. 6 NIH catheter. Normal rate and rhythm undisturbed.

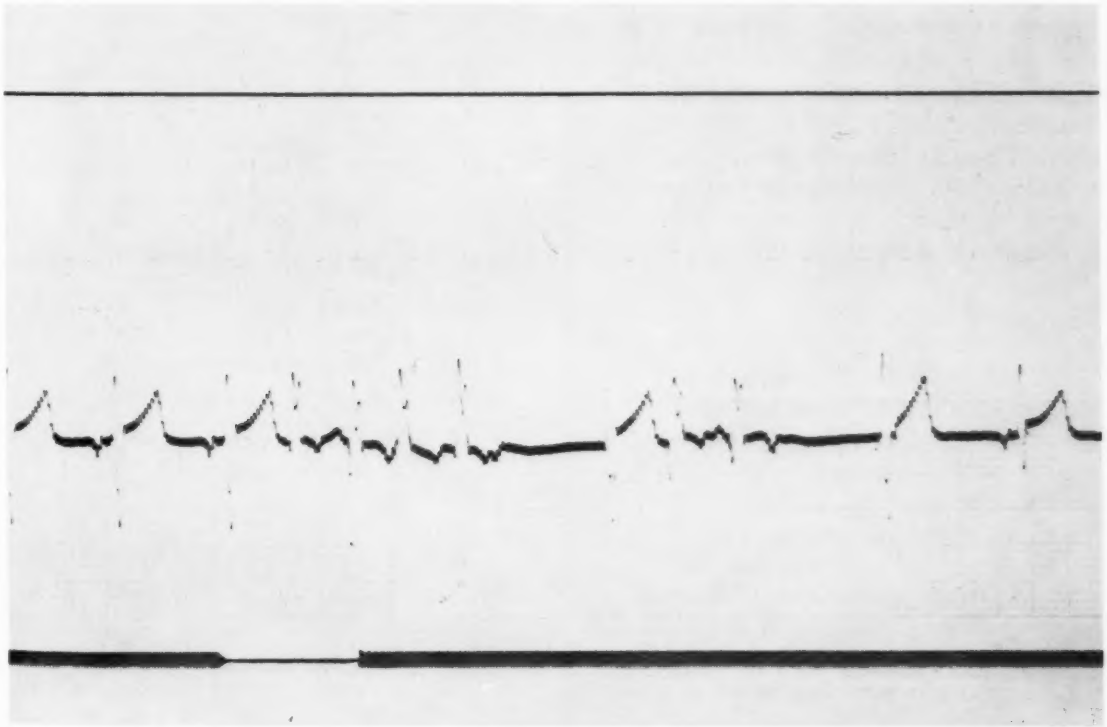

FIG. 3. Seven and one-half cubic centimeters of 70 per cent sodium uroken were injected in 0.8 second through a Rodriguez-Alvarez catheter. This was associated with two short bursts of tachycardia with aberrant ventricular complexes; normal sinus rhythm re-appeared in 3 seconds.

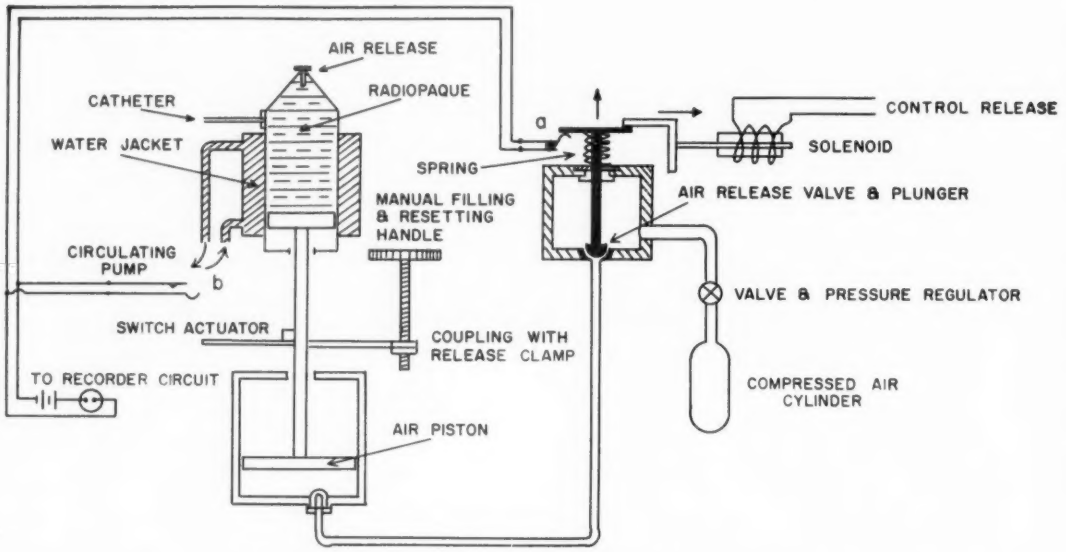

FIG. 4. Diagram of the Gidlund syringe system with the addition of the injection timing device.

pen produces a continuous tracing. When the release control is pressed down, a solenoid is energized and opens contact *a*, which in turn opens the recording circuit; thus the tracing is interrupted. When the piston arrives at the end of its travel, a switch actuator closes contact *b*. The recorder circuit is then re-energized and the tracing reappears.

At the end of the injection, the appropriate length of electrocardiographic tracing paper is detached, relevant information immediately recorded on it in ink, including the patient's name, date, amount of the opaque medium used and size of catheter, and the tracing then becomes a permanent part of the radiologic examination file.

Scott Dunbar, M.D.
The Montreal Children's Hospital
2300 Tupper Street
Montreal 25, Quebec
Canada

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EXPERIENCE WITH MAJOR ARTERIAL VISUALIZATION EMPLOYING RIGHT HEART OR SUPERIOR VENA CAVA INJECTION*

By HOWARD C. BURKHEAD, M.D., GEORGE C. SUTTON, M.D., JOHN B. GRAHAM, M.D., *and* JOHN P. FOTOPOULOS, M.D.
CHICAGO, ILLINOIS

IN EFFORTS to improve the results of rapidly injected intravenous opaque media for visualization of the aorta and its branches (described earlier[1,3,5,7]), injection via a Lehman catheter into the superior vena cava, the right auricle or the right ventricle has been employed in 85 patients during the past year. The technique used, its advantages and disadvantages, will be presented here. No attempt will be made to review the literature on angiography since this has recently been done by Steinberg, Finby, and Evans.[5]

The intent of any diagnostic procedure, of course, is to secure a diagnostic answer with minimum discomfort and risk to the patient. The difficulties and risks of translumbar aortography,[2] direct carotid puncture, and retrograde arterial catheterization, with the attendant difficulties in catheter positioning and the danger of inducing arterial spasm, have given impetus to the use of intravenous arteriography. Direct arteriography does possess certain advantages, since it is a basic principle of contrast visualization that the closer the site of injection to the vessel studied, the better the roentgenologic result. Therefore, it may well be used to supplement the intravenous method.

The advantages of one procedure over the other, or of one supplementing the other, are emerging, and these will be presented in the light of our experience. Since the technique employed in the intravenous method alters the results, a detailed description of our procedures is given here.

TECHNIQUE

In the radiology department a cut down is made on the patient's medial left antecubital vein. In compensated patients a Lehman catheter of maximum size (usually F8 or F10) is then advanced through the vein toward the heart as far as can be done quickly and easily, usually to the superior vena cava. This procedure takes little more time than the insertion of a Robb-Steinberg needle. A continuous drip of normal saline solution with heparin is run through the catheter. In patients suspected of having congestive heart failure, the catheter is advanced into the right auricle or ventricle, and sometimes into the pulmonary artery.

In all cases, during this process the electrocardiographic tracing and intracardiac pressures are constantly monitored on an oscilloscope. Measurement of the right ventricular diastolic pressure gives a quick, rough evaluation of the degree of congestive failure, thus eliminating the need for circulation time studies and the accompanying risks.

After insertion of the catheter, a firm, sterile bandage is applied to the surgical site in order to prevent contamination as well as catheter displacement. Without risk, the patient may then walk or be moved to the serial roentgen-ray camera and be placed in any appropriate body position—supine, oblique or lateral—with the arms freely movable and flexible.

Once the patient is positioned before the camera, approximately 85–90 cc. of warm contrast 90 per cent is injected by a

* From the Departments of Radiology, Medicine and Surgery of the Northwestern University Medical School, Chicago, and the Evanston Hospital Association, Evanston, Illinois.
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pressure pump. (Details for construction of a simple, inexpensive pump are published elsewhere.[6]) Serial arteriograms taken for approximately ten seconds after the injection is completed are sufficient in compensated patients, while arteriograms taken for twenty to thirty-five seconds are necessary for persons with higher than normal right ventricular diastolic pressures. This injection, which requires approximately two seconds, projects a concentrated bolus through the circulation, and its dilution in the arterial tree is minimized by the speed of the injection.

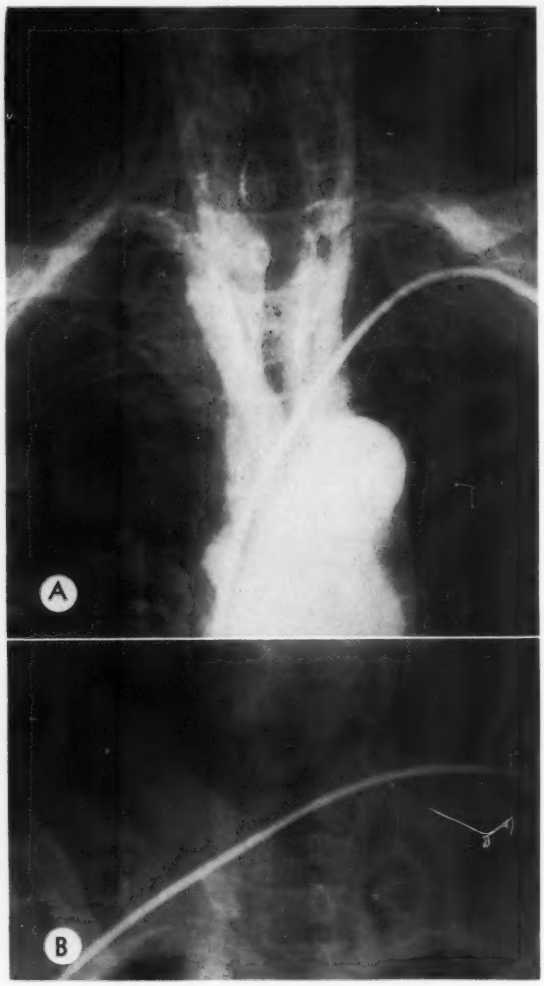

FIG. 1. (*A*) Normal aortic arch, subclavian, carotid and vertebral arteries. (*B*) Elongation, kinking and dilatation of the subclavian and carotid arteries.

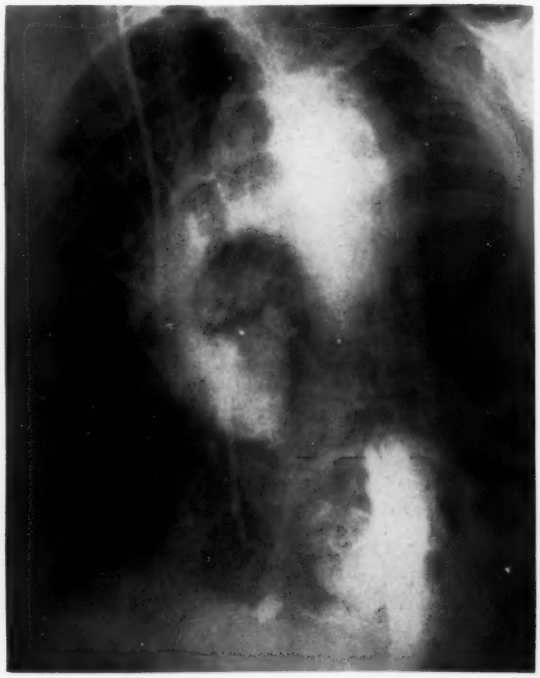

FIG. 2. The ascending aortic arch and a large aneurysm of the proximal thoracic aorta are demonstrated in this oblique arteriogram.

As a rule, a 9 inch roll film Fairchild camera with a maximum speed of two frames per second was used. Since the film is small, second injections were made if exposures in two views were needed.

RESULTS

Eightyfive patients have been examined by this method without serious difficulty. Contrast visualization of the arteries of the neck (innominate, carotid and vertebral) and mediastinum, the thoracic and abdominal aorta, the splenic and renal arteries, and the ileofemoral arteries has been successful (Fig. 1–4).

ADVANTAGES

The advantages of right heart or vena cava injection for peripheral arterial visualization are many. Introduction and advancement of the catheter is simple, painless and safe. General anesthesia is not needed. The measurement of pressures in

the right heart in order to evaluate heart failure and, hence, prolonged circulation time can be done more easily with this technique than with chemical methods of determining circulation times. Irrespective of injection site, the circulation time of a large bolus of contrast material, rapidly injected, has been shown to be much shorter than the circulation time of a small quantity of the medium. In the presence of cardiomegaly or congestive failure, precise circulation times are difficult to determine, and right ventricular diastolic pressures serve as an indicator for taking serial arteriograms over a longer interval.

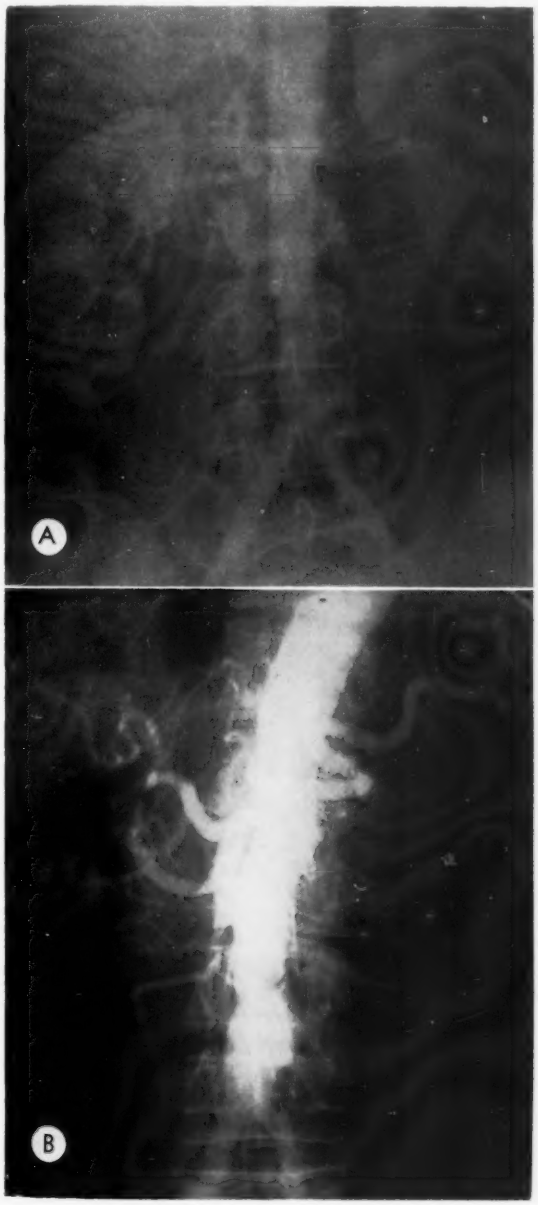

Fig 3 (*A*) Normal aorta, and normal renal and ileofemoral arteries. (*B*) Abdominal aorta demonstrating multiple saccular aneurysms and a defect (probably an atheromatous plaque) in the distal aortic wall.

Serial roentgenography sometimes makes a second injection unnecessary when visualization of a particular artery on one or two arteriograms is not clear.

There has been no occurrence of thrombophlebitis at the site of catheter insertion and, theoretically, its incidence should be reduced by this technique as compared to direct injection of a highly concentrated medium into an arm vein. Since the patient has a flexible catheter inserted into the vein rather than a rigid needle, he may walk, bend his arm, be positioned easily and be moved quickly if he becomes nauseated or uncomfortable after the injection.

Contrast material cannot be extravasated into the soft tissues of the arm, regardless of the pressure applied during the injection. In addition, the injection of the contrast medium into the right auricle or pulmonary artery (in contrast to one or two arm sites) of decompensated persons greatly improves arterial visualization, since the circulating time is shorter.

The pump with its handle and catheter allows the operator to stand at a distance from the patient and also allows him to leave the room upon completion of the injection; this results in low radiation exposure to the operator.

Most important is the apparent absence of possible damage to the aorta, peripheral arteries, or the tissues they supply; contrarily, this may occur with direct puncture or retrograde catheterization.

LIMITATIONS

In our experience with intravenous arteriography we have found that injection into the vena cava or right heart is superior to

injection into an arm for reasons of the patient's comfort, simplified technique, rapidity of injection and lessened dilution of the opaque medium. Because of the cardiac perfusion, patients may experience temporary myocardial changes following the injection, as is shown in Figure 5. However, no permanent cardiac alteration has been observed by us to date.

It is true that the best examination of any vessel is made with the medium injected directly into it, and that any intravenous method of arteriography will not result in as clear a visualization because of dilution in the heart and lung. However, because of the size of the aorta and its major branches, volume multiplied by the unit concentration of the contrast material is sufficient to give good (not excellent) visualization. Precise delineation of details

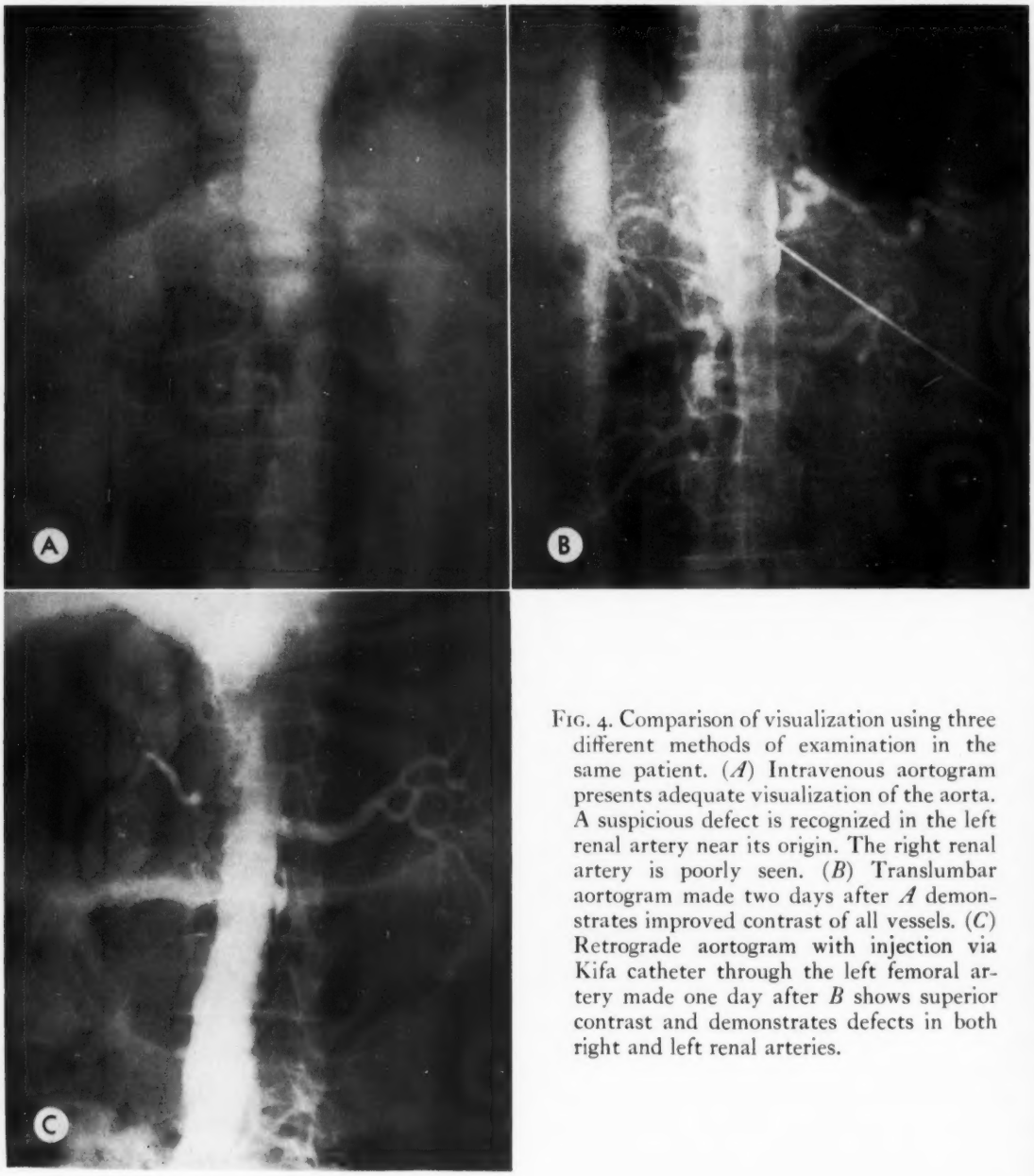

FIG. 4. Comparison of visualization using three different methods of examination in the same patient. (*A*) Intravenous aortogram presents adequate visualization of the aorta. A suspicious defect is recognized in the left renal artery near its origin. The right renal artery is poorly seen. (*B*) Translumbar aortogram made two days after *A* demonstrates improved contrast of all vessels. (*C*) Retrograde aortogram with injection via Kifa catheter through the left femoral artery made one day after *B* shows superior contrast and demonstrates defects in both right and left renal arteries.

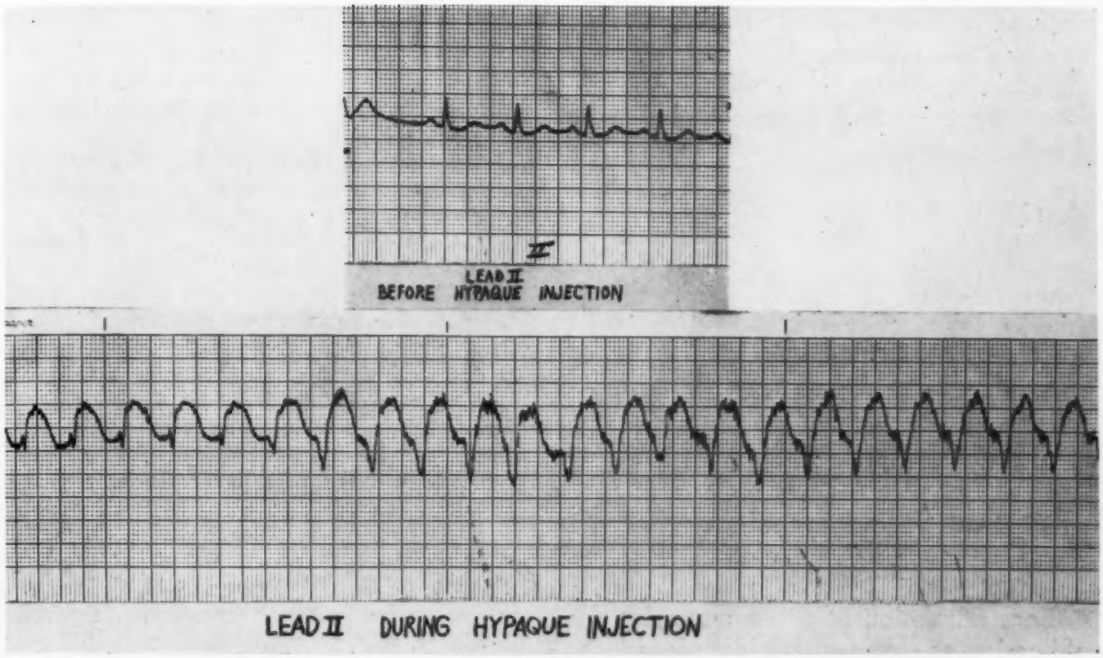

Fig. 5. Monitoring electrocardiogram taken before and during catheter intravenous aortography in a patient seventy-two years old with known arteriosclerotic heart disease. The changes subsided in five hours without treatment and represent the most marked changes seen.

and of vessels less than 2 mm. in diameter is poor.

INDICATIONS OF CATHETER-VENOUS ARTERIOGRAPHY

Our experience has shown that catheter-venous arteriography is indicated as a procedure in the following conditions:

1. Disease of the larger arteries which cannot be safely reached by retrograde arterial catheterization or direct puncture. (Specifically, these are the vertebral, innominate, subclavian, and common carotid arteries and the proximal portions of the internal and external carotid vessels.) We believe the risk of damage to the brain or to a sclerotic carotid artery is negligible, and the contrast visualization is adequate for the surgeon. This procedure, in our experience, does not have diagnostic value for details of cerebral arteries far beyond the carotid bifurcation, because of poor detail and overlapping of arteries.

2. Lesions of the thoracic and abdominal aorta, or its major branches, when there is disease of the vessel wall which makes the risk of puncturing or catheterizing the aorta or femoral artery excessive.

3. Suspected major arterial disease. In this instance, catheter-venous arteriography acts as a screening procedure and the presence and character, or absence, of all gross pathology can be determined. This may be diagnostic and definitive in itself. If more precise delineation of smaller arteries is then needed, selective arteriography by direct puncture or retrograde catheterization can be done with foreknowledge of the exact site to be visualized and assurance of the absence of disease in the vessel to be punctured. The use of catheter-venous arteriography as a screening procedure for further arteriography or catheterization has proved to be unusually valuable and seems to offer broad possibilities.

SUMMARY

Our experience with the rapid injection of an opaque contrast medium into the right heart shows that there are many ad-

vantages to this procedure for visualizing the aorta and its major branches. The examination facilitates the application of additional selective techniques for small vessel visualization.

Howard C. Burkhead, M.D.
Evanston Hospital Association
2650 Ridge Avenue
Evanston, Illinois

The authors wish to thank Miss Winifred McGillivray and Miss Patricia Connelly for their technical assistance. We also wish to thank Winthrop Laboratories, Inc. for the supply of hypaque M 90 per cent which was used for some of the examinations.

ADDENDUM

Since admission of this manuscript for publication, the intravenous injection method for arteriography has been successfully employed using the Elema Schönander unit as well as cineroentgenography. The latter, cine technique, with its low radiation exposure and expense has allowed longer filming. This decreases the necessity of prior determination of the presence of heart failure and its prolonged circulation time.

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VENOANGIOGRAPHY*

By ALVARO RONDEROS, M.D., EDGAR W. BRANYON, Jr., M.D., J. THOMAS CARLIN, Jr., M.D., *and* JAMES DOYLE, M.D.
BIRMINGHAM, ALABAMA

THE purpose of this paper is to report our technique, experience, and results with a method of angiography currently in use at the University Hospital, Birmingham, Alabama.

The historical aspects of the development of angiography, angiocardiography, and aortography have been reviewed recently by Steinberg *et al.*[12–14] and Kincaid and Davis.[8] The development of similar procedures and the advantage of intravenous aortography over the methods which require direct puncture of the arteries have been discussed by Bernstein *et al.*[1] and by Greenspan and his associates.[7]

Improvement in roentgenographic equipment, the use of rapid cassette changers[2,3] and pressure injection, and refinements in contrast media, which are now less toxic and more soluble[6,15] and can be employed in larger amounts,[9,10–13,14] have made it possible to enhance visualization of the major arteries by injection through the venous route.

TECHNIQUE

Under local anesthesia using one per cent novocaine, the right antecubital vein is isolated. A Lehman cardiac catheter No. 9 (Fig. 1) is inserted through the basilic vein into the axillary vein or, preferably, the superior vena cava. When there is any doubt as to the exact location, fluoroscopy is performed to observe the position of the tip of the catheter. We prefer to use the right arm; however, we have used the left arm on six occasions. We have also used the right femoral vein, and the right superficial jugular vein. Determination of the circulation time is made only when there is clinical evidence that it may be abnormal.

An injection of 95 to 100 ml. sodium and n-methylglucamine salts of diatrizoic acid* diluted to 70 to 75 per cent solution and warmed to 37° C. is made using the Elema-Schönander automatic injector at a pressure of 5 pounds per square centimeter. With a Sanchez-Perez seriograph, twelve exposures are made in each examination at intervals of one-half to two seconds.

For visualization of the thoracic aorta and neck vessels, the first angiogram of the series is taken five seconds after completion of the injection. When the abdominal aorta is the object of study, the series is usually started eight seconds after completion of the injection.

We use 300 ma., one-tenth second and a kilovoltage varying from 70 to 110, according to the thickness of the exposed region. The distance from tube to table top is 40 inches. A preliminary roentgenogram is always made to check the technique, the position of the patient and the mechanical functioning of the equipment.

MATERIAL

One hundred and nine venoangiographies were performed during the period from August, 1959 to May, 1960 in the Radiological Department of the University Hospital† and they constitute the material for the present article. The ages of the patients were between fourteen and seventy-five years.

A single dose of 95 to 100 ml. of 75 per cent hypaque was used in 101 patients. In 8 patients a second injection of the same volume and concentration of the medium was made after an interval of fifteen to

* Supplied as "hypaque" by Winthrop Laboratories in 90, 75, and 50 per cent solutions.

† The first 67 of these cases were reported at the Alabama State Medical Meeting in April, 1960 by Drs. Champ Lyons and Alvaro Ronderos.

* From the Department of Radiology, Medical College of Alabama, Birmingham, Alabama.

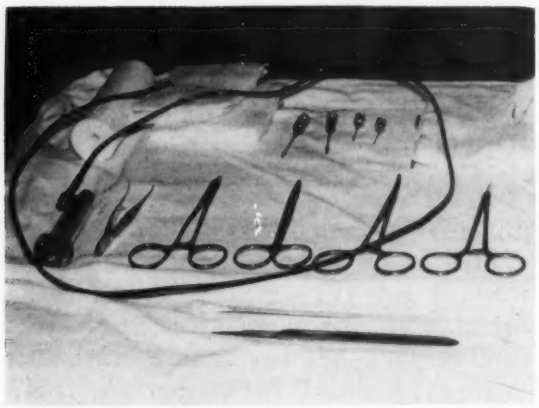

FIG. 1. Cut-down tray with No. 9 Lehman cardiac catheter.

twenty minutes for technical reasons or for complementary studies.

RESULTS

Sixteen venoangiograms, out of the total of 109, were considered to be unsatisfactory for roentgenologic interpretation. Table 1 summarizes our total experience regarding the effectiveness of venoangiography in the 109 examinations.

In general, the quality of the angiograms was excellent with satisfactory visualization of the cardiac chambers and the ascending portion of the aorta. The great vessels arising from the aortic arch were adequately visualized in three-fourths of the cases. It is very important that careful positioning of the patient and satisfactory rotation of the head be done to prevent overlapping of the major neck vessels.

The abdominal aorta is not visualized as distinctly as the thoracic aorta, but there is usually adequate demonstration of aneurysms or large atheromatous plaques. This examination has proved inadequate to exclude the possibility of the presence of small plaques or minimal strictures of the renal arteries.

In the workup of hypertensive patients, we feel that direct or retrograde aortography is indicated rather than venoangiography.

TABLE I

VENOANGIOGRAPHY

Area	Satisfactory Examination	Unsatisfactory Examination	Total
Mediastinal and Pulmonary Vessels	23	0	23
Neck Arteries	31	8	39
Descending Aorta	14	2	16
Abdominal Aorta	22	4	26
Pelvic and Femoral Arteries	3	2	5
Total	93	16	109

1. MEDIASTINUM AND PULMONARY VESSELS

A total of 23 patients was examined.

In 2 patients with carcinoma of the lung, a major vessel involvement was demonstrated and used as a criterion for inoperability (Fig. 2). In 3 patients, angiograms excluded a pulmonary sequestration of the lung by proving the absence of anomalous arteries. A suspected pulmonary arteriovenous fistula was clearly demonstrated on the angiogram in 1 patient (Fig. 3).

The distance between the endocardium and pericardium was a matter of interest in 2 patients during their recovery from wounds of the heart. This type of measure-

FIG. 2. Left upper lobe bronchogenic carcinoma occluding the left pulmonary artery (arrows).

Fig. 3. J. W. C., a thirty-eight year old white male with Rendu-Osler-Weber's disease. Arrow indicates associated pulmonary arteriovenous malformation.

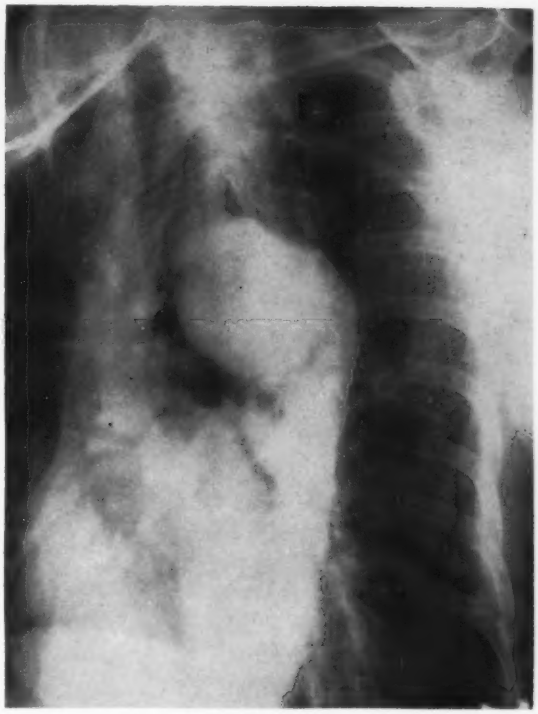

Fig. 4. Aortic arch aneurysm. The examination was performed with the patient supine and the left side elevated 20 degrees.

ment is also useful in the recognition of myocardial hypertrophy and ventricular aneurysms.

Mediastinal tumors were suspected in 12 patients. In 2 of these, aneurysms were identified (Fig. 4). In 3, the masses were

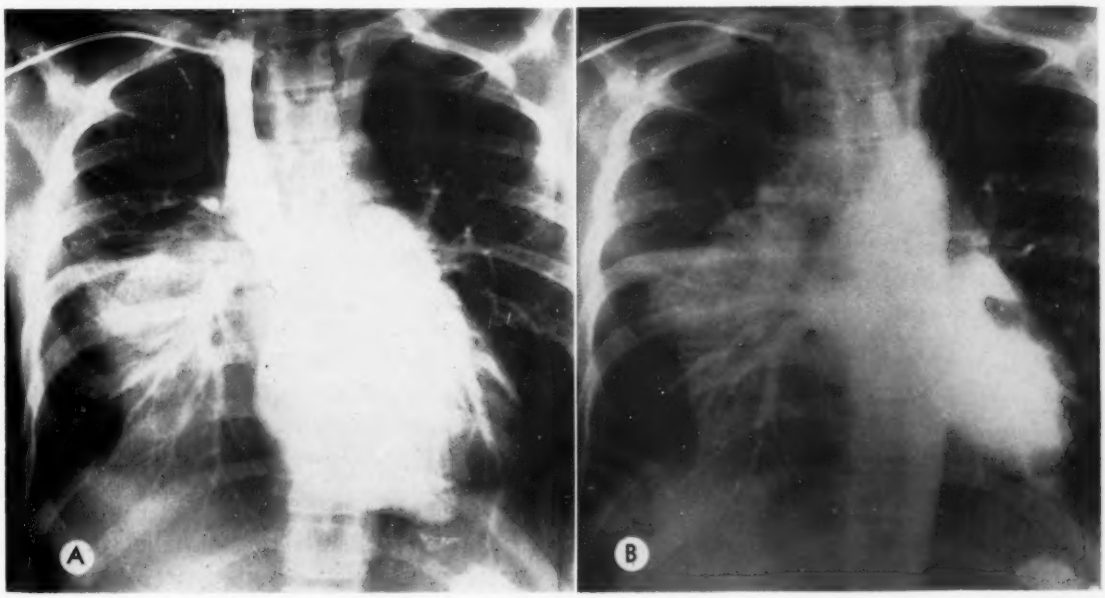

Fig. 5. A mediastinal mass was indistinguishable from the right heart border on plain roentgenograms. Venoangiograms demonstrate (*A*) early and (*B*) late cardiac filling phases outlining the heart chambers separate from the mass. Subsequently, Hodgkin's disease was proved.

FIG. 6. Right sided aortic arch.

confirmed to be extrinsic to the heart and major vessels (Fig. 5, *A* and *B*). In 1 patient who was suspected of having a pericardial cyst, the venoangiogram demonstrated a dextroversion of the heart. One patient with a superior mediastinal mass was proved, angiographically, to have a right aortic arch (Fig. 6). In another patient, a large left hilar mass seen on the plain roentgenograms was shown by venoangiography to be a dilatation of the pulmonary artery (Fig. 7). Four other examinations were considered to be normal.

FIG. 7. A forty-three year old white female with asymptomatic dilatation of the common pulmonary artery.

FIG. 8. Complete occlusion of the right internal carotid artery (arrow).

In general, the quality of the venoangiograms and the concentration of the contrast medium were excellent in these examinations.

2. NECK ARTERIES

The vessels arising from the aortic arch were studied in 39 patients for cerebrovascular insufficiency and occlusive diseases of the subclavian arteries. In 15 patients, occlusive disease was demonstrated either

Fig. 9. Normal study demonstrating the great vessels of the aortic arch.

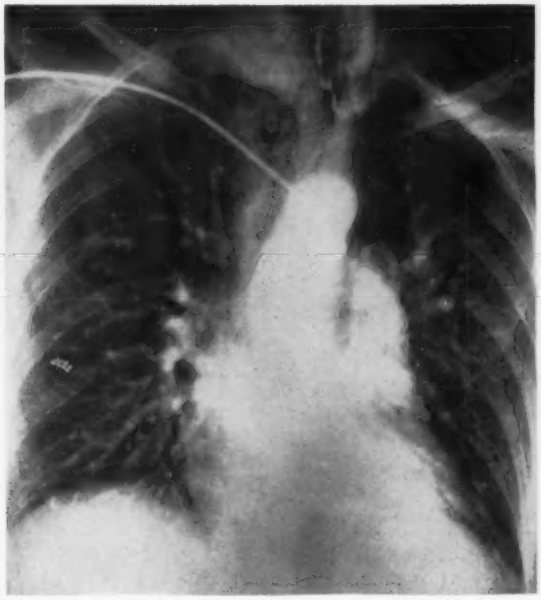

Fig. 10. Fusiform aneurysm of the right subclavian artery.

by showing the area of narrowing or by lack of filling of one or more vessels (Fig. 8). Six examinations were interpreted as normal (Fig. 9). In 1 patient, a fusiform aneurysm of the right subclavian artery was found (Fig. 10) and, in another, a traumatic carotid-jugular fistula was demonstrated in the left neck (Fig. 11). In 5 patients, where endarterectomy or prosthetic by-pass had been performed, this examination demonstrated patency of the graft in 2 cases and occlusion in 3. Occlusion of the subclavian artery was shown in 3 patients (Fig. 12), in 1 of whom it was extrinsic and was relieved by scalenotomy. Eight studies were considered to be unsatisfactory.

3. DESCENDING AORTA

Examination of this portion of the aorta was performed in 16 patients. An aneurysm, suspected in 6 instances, was demonstrated in 4 and excluded in 2. A dissecting aneurysm was suspected in 2 cases, being verified in 1 (Fig. 13) and excluded in the other. In another patient, after aortic surgery, excellent visualization of the anastomotic line was demonstrated (Fig. 14).

In 7 patients with suspected posterior mediastinal tumors, the examination

Fig. 11. Left carotid-jugular fistula with marked dilatation of the vein.

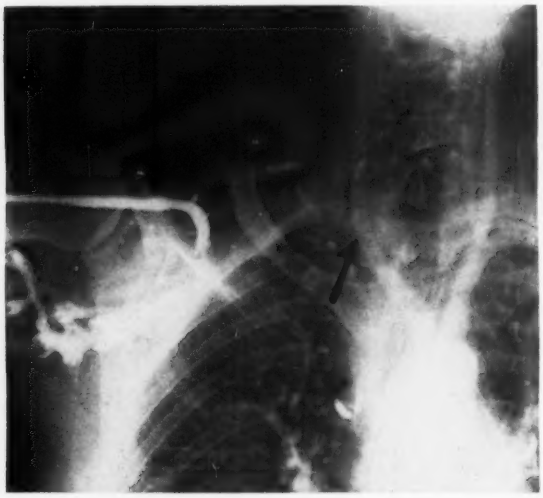

FIG. 12. Right subclavian artery occlusion by an atheromatous plaque at its origin (arrow).

showed that 2 of them had a tortuous aorta, 2 had extravascular masses, and 1 was normal; 2 examinations were unsatisfactory.

4. ABDOMINAL AORTA

Examination of the abdominal aorta in 26 patients demonstrated an aneurysm in 3 (Fig. 15). Unilateral renal artery occlusion was confirmed in 2 cases. Figure 16 is a venoangiogram showing the patency of an

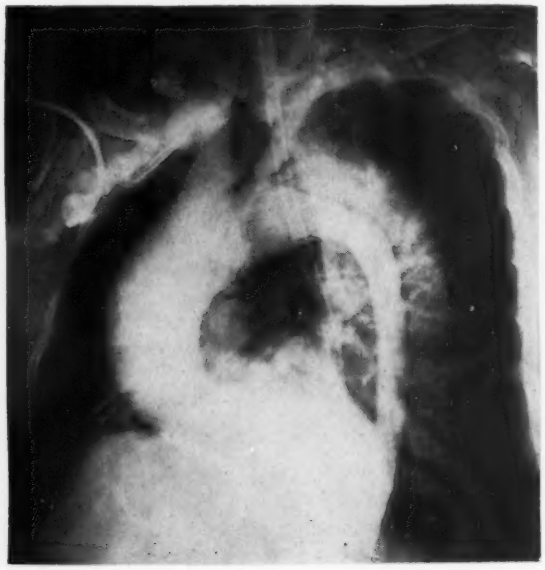

FIG. 13. Dissecting aneurysm of the descending thoracic aorta. Note "double lumen" with the false lumen projected posteriorly.

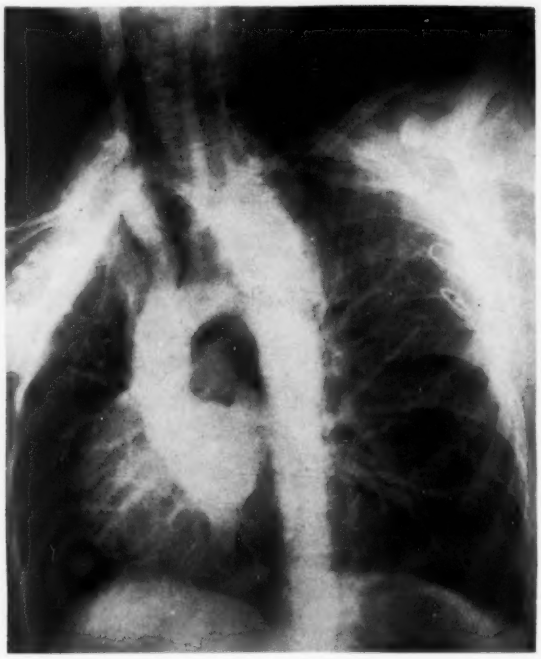

FIG. 14. Postoperative narrowing of the aorta at the site of a resected coarctation.

FIG. 15. Fusiform aneurysm of the abdominal aorta below the renal arteries.

Fig. 16. Aortic-renal graft.

aortic-renal shunt performed for relief of hypertension. In the remaining patients, venoangiography was elected for evaluation of occlusive disease of the abdominal aorta with 8 examinations normal (Fig. 17), 8 indicating minimal to moderate atherosclerosis and 4 being unsatisfactory for interpretation.

Fig. 17. Normal abdominal aorta.

Fig. 18. Normal pelvic vessels.

Fig. 19. Extravasation of medium into the right supraclavicular soft tissues.

5. PELVIC AND FEMORAL ARTERIES

Venoangiography for study of the pelvic and femoral arteries was done on 5 patients. Two of these studies were unsatisfactory; a lesion was demonstrated in 2 instances and excluded in 1 (Fig. 18).

COMPLICATIONS

Usually the patients experienced a generalized flush immediately after the injection of the contrast medium and, frequently, they noted a metallic taste. Nine patients in this series became nauseated and 2 of these vomited. Two of the patients developed a severe headache which lasted for two to three hours. Another patient developed a seizure forty-five minutes after injection of the contrast medium; however, since this patient was a known epileptic, the significance of this seizure cannot be ascertained.

In 2 patients, extravasation of the medium occurred. In 1 of these, the tip of the catheter was located in the lower neck and almost the entire amount of the medium infiltrated the neck (Fig. 19). The patient experienced immediate severe local pain at the site of extravasation. Roentgenograms made on the following day showed complete disappearance of the contrast medium from the soft tissues and the patient was asymptomatic. This patient has been followed for one month without evidence of soft tissue necrosis or other complication.

In another patient, infiltration of approximately 5 cc. of contrast medium occurred in the upper mediastinum through a ruptured collateral vein and, again, temporary local pain was experienced but the medium was completely absorbed in six hours and there were no sequelae.

No incidence of allergy to this contrast medium occurred in these 109 patients.

SUMMARY

A total of 109 examinations, during the period from August, 1959 to May, 1960, was done at the University Hospital in Birmingham, Alabama.

We have emphasized the use of large amounts of concentrated contrast medium (95 to 100 ml. of 70 to 75 per cent hypaque), and the pressure injection of it through a catheter placed in the superior vena cava.

We believe that larger amounts of contrast medium can be used in the future with further inprovement of the diagnostic capabilities of this technique.

From our experience, this method of venoangiography is a safe and simple procedure that can be done under local anesthesia with minimal complications.

The results have encouraged us to continue the use of this method for the study of the neck vessels and the thoracic and abdominal aorta.

Alvaro Ronderos, M.D.
Department of Radiology
University Hospital
Birmingham 3, Alabama

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BUCKLING OF THE INNOMINATE ARTERY SIMULATING ANEURYSM AND TUMOR*

By HAROLD J. SCHNEIDER, M.D., *and* BENJAMIN FELSON, M.D.
CINCINNATI, OHIO

BUCKLING of the innominate artery is a relatively common entity that has had limited recognition. It is of particular roentgenologic importance because it is often mistaken for an aneurysm or a tumor of the lung or mediastinum.

Buckling of the right common carotid artery was first described anatomically by Coulson,[1] in 1852. More recently, buckling of the carotid and/or innominate artery has been described in a number of nonradiologic journals.[2,6,7,8,10,11]

On reviewing the approximately 125 cases of carotid or innominate artery buckling reported in the literature, a number of interesting facts came to light: (1) Almost all patients were over forty years of age. The few younger patients, particularly those under thirty, had coarctation of the aorta. (2) The great majority of patients were females. (3) Most patients were obese and had clinical evidence of arteriosclerosis, hypertension, or both. (4) Cardiomegaly was a frequent finding, usually on the basis of hypertension although sometimes attributable to aortic insufficiency. (5) A small pulsating mass was often palpable in the right supraclavicular fossa. (6) The innominate artery was affected far less frequently than the carotid.

Three recent cases of buckling of the innominate artery encountered at the Cincinnati General Hospital illustrate the importance of recognizing this condition.

REPORT OF CASES

CASE I. This sixty-one year old white male complained of intermittent aching of the lower left chest, pain being accentuated by exercise. Exertional dyspnea was also present.

Physical examination revealed a blood pressure of 150/55. The cardiac and respiratory rates were normal. There were prominent pulsations over the arteries in the neck, but no mass was palpable in the supraclavicular region. There was no tracheal tug. The heart was moderately enlarged, with left ventricle preponderance and the murmur of aortic insufficiency.

Routine laboratory findings were normal. Blood and cerebrospinal fluid serologic tests for syphilis were negative.

Roentgen examination of the chest showed left ventricular enlargement. The thoracic aorta was moderately dilated, elongated, and uncoiled. A right superior mediastinal mass was visible, blending inferiorly with the arch of the aorta. There was no evidence of calcification within the mass. The trachea was normal. The left superior mediastinum above the aortic knob was moderately prominent (Fig. 1). On fluoroscopy the mass appeared to pulsate. It diminished in size with the Valsalva maneuver but did not move with swallowing. The esophagus appeared normal.

The initial diagnosis was innominate artery aneurysm. Angiocardiography, performed to verify this diagnosis and to exclude neoplasm, revealed, to our surprise, that the mass merely represented a dilated buckled innominate artery (Fig. 2, *A* and *B*). The left subclavian artery showed similar elongation, dilatation, tortuosity, and lateral displacement, accounting for the prominence on the left side.

CASE II. This fifty-two year old white male had been followed for a period of eighteen years because of rheumatic heart disease with aortic and mitral valvular involvement. The aortic valvular disease predominated, the degree of insufficiency having increased over the years. The initial blood pressure was 150/40 but, as the years passed, the systolic pressure rose to 260. More recently, roentgenographic evidence of widening of the right superior mediastinum had appeared (Fig. 3). The resulting mass blended inferiorly with the arch of the aorta and slightly indented the esophagus. It was felt to

* From the Department of Radiology, University of Cincinnati College of Medicine.

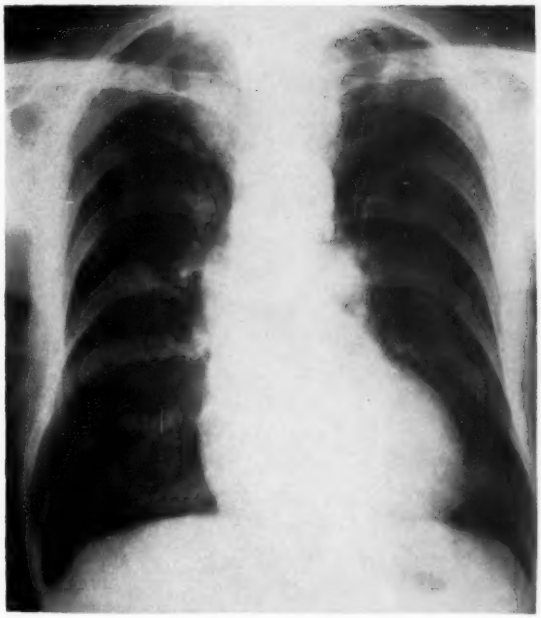


Fig. 1. Case 1. There is widening of the superior mediastinal shadow predominantly to the right. The aorta is dilated and the left ventricle appears slightly enlarged.

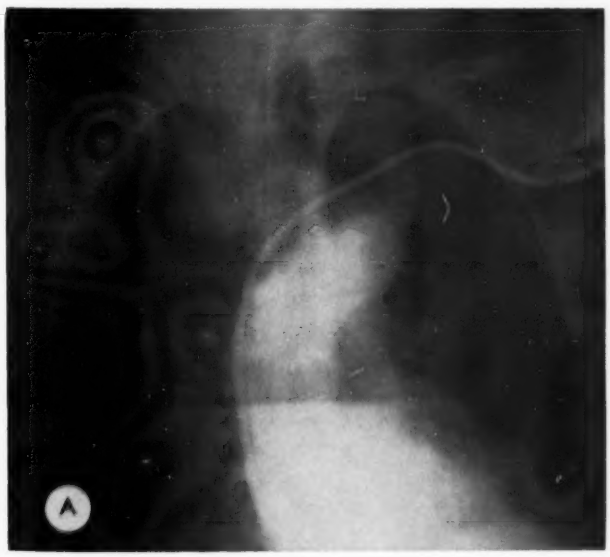
represent an innominate artery aneurysm despite the fact that, on fluoroscopy, it showed only minimal pulsations and these appeared to be transmitted rather than expansile. Because of the progressive aortic insufficiency, insertion of a Hufnagel valve was contemplated. Angiocardiography was performed to evaluate the extent of the innominate artery aneurysm. This showed no aneurysm at all, but a striking degree of buckling of the innominate artery (Fig. 4, *A* and *B*).

The patient's condition did not permit the Hufnagel operation and he rapidly deteriorated and expired. Permission for autopsy was not granted.

Case III. This sixty-two year old Negro woman was found to have obesity, hypertension, moderate cardiomegaly, and anemia. Serologic studies for syphilis were negative.

On the initial chest roentgenogram, a small nodular mass, about 2 cm. in diameter, was discovered in the medial portion of the right apex (Fig. 5*A*). The trachea appeared normal. Serial chest roentgenograms over the next five months suggested slight enlargement of the mass. Laminagraphy (Fig. 5*B*) showed no calcification within it. The medial margin appeared to blend with the superior mediastinum.

Because of the likelihood of neoplasm, surgical exploration was advised. However, a medical student called attention to a slight fullness in the right supraclavicular fossa with prominent pulsations. A vascular lesion was now suspected and angiocardiography was performed. This showed that the mass represented a dilated buckled innominate artery (Fig. 6, *A* and *B*).



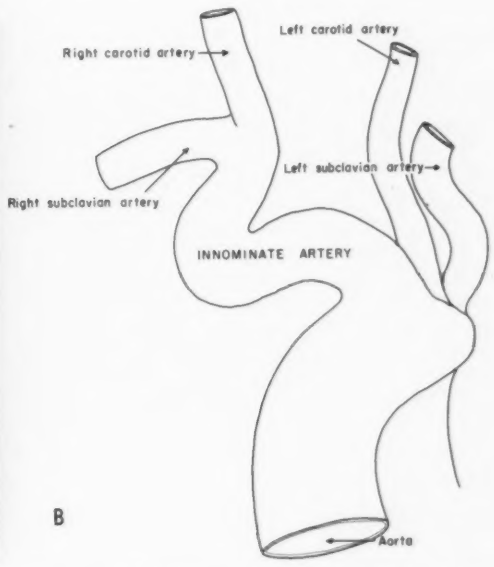


Fig. 2. Case 1. (*A*) Angiocardiogram showing dilatation and tortuosity of the great vessels arising from the aorta, with marked buckling of the innominate artery. (*B*) Drawing of *A*.

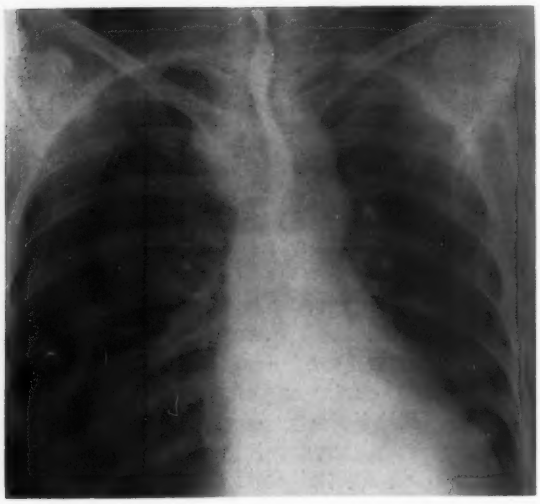


FIG. 3. Case II. A right superior mediastinal mass is present, slightly indenting the esophagus. There is fullness of the left mediastinum above the aortic knob. Moderate cardiomegaly is present.

DISCUSSION

The normal innominate artery is a relatively short vessel, only 5 cm. in length. It has three points of fixation, the arch of the aorta, the right subclavian artery as it passes under the scalenus muscle, and the carotid artery, in turn fixed by the internal and external carotid branches within the neck.[3,5] When, because of atherosclerosis, the thoracic aorta dilates, elongates, and uncoils, the aortic arch moves cephalad, carrying with it the origin of the innominate artery. Since it is fixed superiorly, the short innominate artery can compensate only by buckling or kinking. This process is further accentuated by atherosclerotic elongation and dilatation of the innominate artery itself.

In none of our 3 cases was the correct diagnosis made from the conventional roentgenograms. In 2 of the cases the working diagnosis was aneurysm, while in the third it was pulmonary neoplasm.

Nevertheless, we now believe it is possible to make a presumptive diagnosis of innominate artery buckling in most cases. Evidence of arteriosclerosis, hypertension, cardiac disease, and in particular a small pulsating mass in the right supraclavicular fossa or lower cervical region are helpful clinical signs. Most of the following roentgen signs are usually present: contiguity of the mass with the aortic arch in all projections; a smooth lateral border; linear calcification; prominence of the left superior mediastinum above the aortic knob, indicating a similar process in the subclavian artery; and evidence of atherosclerosis of the thoracic aorta.

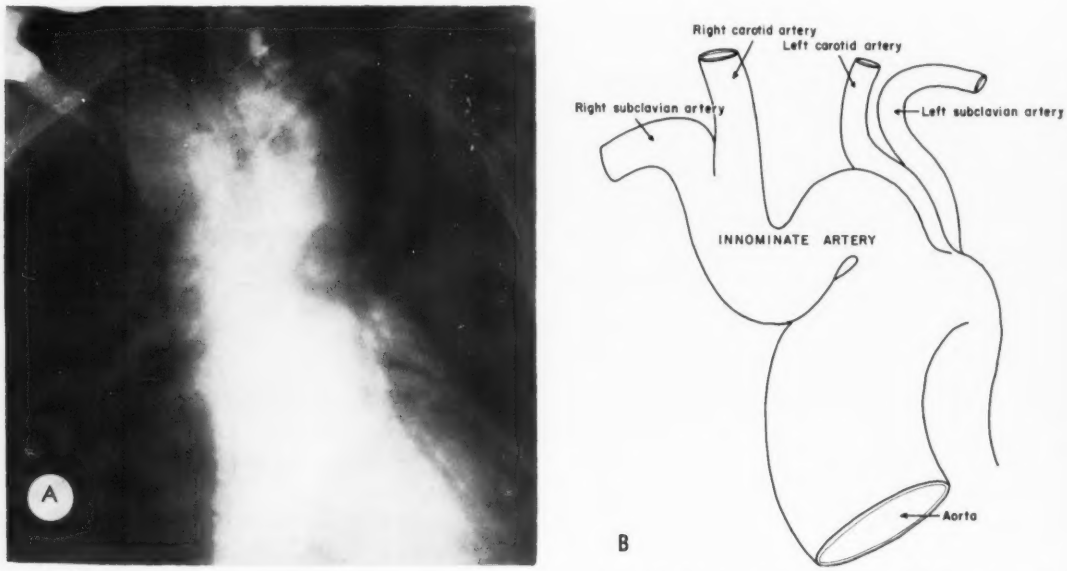


FIG. 4. Case II. (*A*) Angiocardiogram showingthe dilated and buckled innominate artery. (*B*) Drawing of *A*.

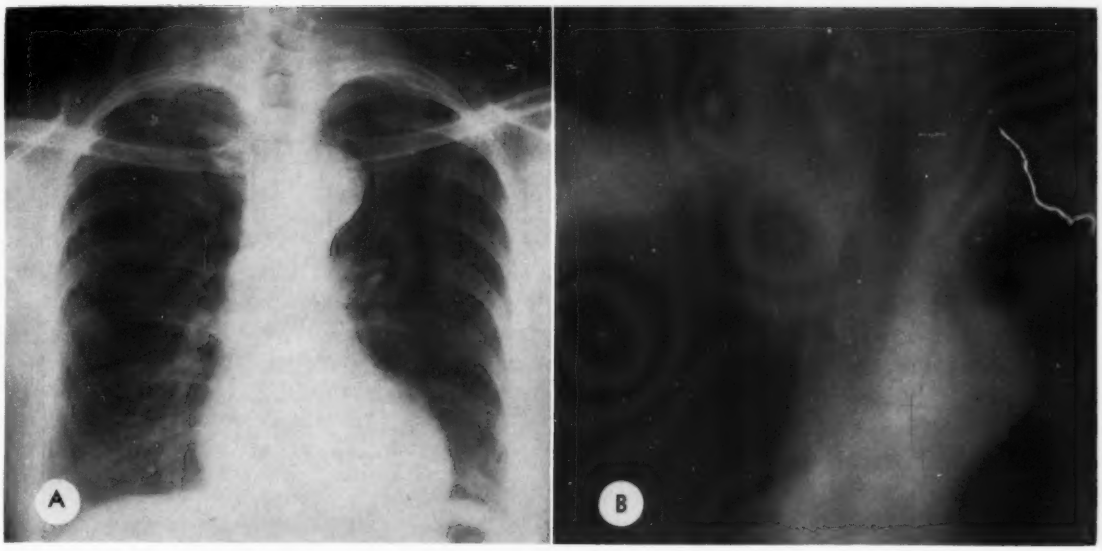


Fig. 5. Case III. (*A*) There is a small lobulated density in the medial portion of the right apex. (*B*) Laminagram suggests an intrapulmonary nodule. It appears to blend with the mediastinal shadow.

Fluoroscopy is of limited value in the differential diagnosis, since intrinsic pulsations may also occur with aneurysm. Furthermore, it is often difficult to distinguish intrinsic pulsations from the transmitted ones seen with nonvascular masses adjoining the aorta or great vessels.[9] Tracheal tug and movement of the mass with swallowing are usually absent in innominate artery buckling.

Bronchography has little to offer. Laminagraphy is helpful in demonstrating the calcified plaques, when these are present.

The definitive diagnosis can be made by catheter aortography or angiocardiography.[4] Of the two, the former gives the better delineation of the arteries. The use of a blind tip catheter with side holes is preferred in order to avoid propulsion of the

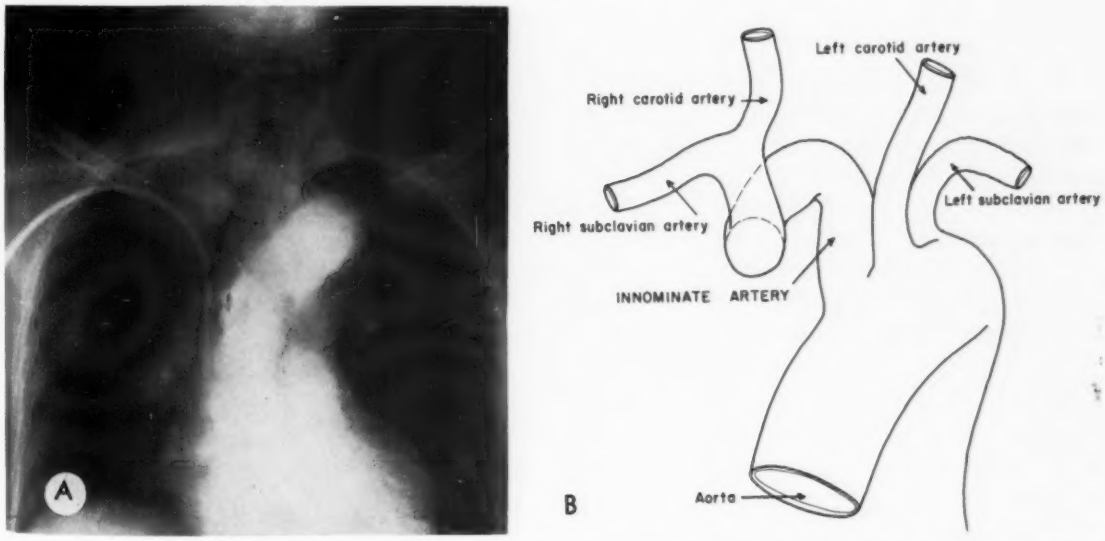


Fig. 6. Case III. (*A*) Angiocardiogram demonstrates a tortuous kinked innominate artery. (*B*) Diagram of *A*.

catheter by the jet of the injection. Failure of catheter passage due to obstruction by thrombosis, atheroma, or arterial kinking is less likely to occur with the femoral than with the brachial artery route.

On the other hand, angiocardiography will usually result in opacification, as in the present cases. It should be attempted first, as it is the simpler and safer method. The contrast medium can be injected into the antecubital vein through a Robb-Steinberg 12-gauge cannula or into the superior vena cava or right heart by means of a blind tip catheter. The latter site, of course, results in less dilution of the contrast substance. Angiocardiography should be used only in cases in which the arm-to-tongue circulation time is normal, or nearly so, and in which cardiovascular shunts are absent, since the dilution factor will otherwise be too great for satisfactory opacification of the innominate artery. If visualization of the innominate artery is unsuccessful by the venous method, catheter aortography may be performed on another day.

Though angiography is time-consuming and entails a small risk, it should always be used before operation for mass lesions in this region. Since the diagnosis of buckling of the great vessels carries with it no serious implications, unnecessary surgical intervention may thereby be averted.

SUMMARY

Buckling of the innominate artery is a relatively frequent condition which is often mistaken for aneurysm or neoplasm. Angiography is the only definitive method of diagnosis. Since it is innocuous, consideration of this entity in the differential diagnosis of right superior mediastinal or pulmonary masses may avert unnecessary surgical explorations. Three cases in which the initial roentgen diagnosis was incorrect are reported.

Harold J. Schneider, M.D.
Department of Radiology
University of Cincinnati College of Medicine
Cincinnati, Ohio.

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THE LOCALIZATION OF PORTAL OBSTRUCTION BY SPLENOPORTOGRAPHY*

By INGEMAR BERGSTRAND, M.D.†
CHICAGO, ILLINOIS

THE technique of splenoportography was introduced less than ten years ago.[1] At first, enthusiasm about its possibilities was great. It was claimed that with this new method of examination the exact location of any portal obstruction could be determined.[2,7,9] However, more recent experience has shown that in many cases the correct location of the obstruction is difficult to identify. Sometimes the examination may even give a completely false indication as to the site of obstruction.[3,4,6,8,10,13,14]

The two means by which any splenic or portal obstruction can be determined roentgenographically are: (1) by studying the visualized portions of the splenic and portal veins, and (2) by analyzing the type of collateral circulation which is demonstrated. The farthest point of visualization of a vessel does not always indicate the site of obstruction. The discrepancy may be due to exposure of the film before the contrast medium has filled the patent splenoportal pathway.[5,9] Serial roentgenograms of at least fifteen seconds are necessary to get optimal visualization of the portal system if its circulation is slow. In some cases with severe vascular obstruction, the part of the vessel adjacent to the obstruction may be patent but filled with blood circulating away from the obstruction to collateral pathways. This is possible because there are no valves in the portal system. As has been shown in animal experiments, in splenoportography contrast medium cannot be forced against the flow of blood and will, therefore, not outline the patent vessel up to the obstruction, even if serial roentgenograms covering a delayed time are obtained.[4]

Analysis of the type of collateral circulation is of help in locating any obstructive lesion.[11,12] If the vascular obstruction is intrahepatic, the collateral vessels will drain the congested vascular area toward the low pressure systemic veins and not to the liver. This is called a hepatofugal (away from the liver) collateral circulation. On the other hand, if the obstruction is extrahepatic, the collateral circulation will, as a rule, develop toward the portal system behind the obstruction and toward the liver where, in both locations, the portal pressure is normal. This is called a hepatopetal (toward the liver) collateral circulation. However, experience has shown that sometimes the collateral vessels are incompletely filled by the splenic injection and the parts which fill may give misleading information as to the location of the obstruction.

MATERIALS AND RESULTS

In order to study the possibility of determining the correct location of any splenoportal obstruction by splenoportography, two groups of patients from the material of the University of Lund were selected. The first group consisted of 91 cases of proved intrahepatic obstruction, in most instances due to cirrhosis, with patent extrahepatic vessels. The second group consisted of 19 patients with proved extrahepatic obstruction and a normal liver. Cases with both intra- and extrahepatic obstruction are not included in this analysis. In 85 of the 91 cases with cirrhosis, the contrast medium passed through the splenic and portal vessels and reached the liver. The porta hepatis was seen after a varying time of two to eight seconds following the injection. Thus, by the contrast visualization of splenic and portal veins, the presence of

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† Assistant Professor (Research Scholar), Department of Radiology, The University of Chicago, and Assistant Professor, Department of Radiology, University of Lund, Lund, Sweden.

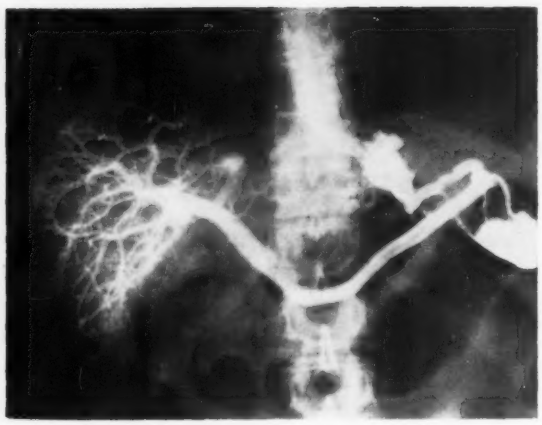

Fig. 1. Intrahepatic obstruction. Hepatofugal collateral circulation is entirely through short gastric veins toward the esophageal veins.

any extrahepatic obstruction could be ruled out. The collateral vessels in these cases were always hepatofugal, directed away from the liver. Figures 1, 2 and 3 illustrate some of these cases with patent splenic and portal veins and hepatofugal collateral circulation due to intrahepatic obstruction.

In cases with an advanced degree of intrahepatic obstruction, there was a very slow circulation through splenic and portal veins and only a small part of the injected contrast medium could reach the liver (Fig. 4, *A* and *B*). Most of the contrast medium, however, drained through hepatofugal collaterals to the left renal vein and inferior vena cava (Fig. 4*C*). It is easy to imagine what will happen when intrahepatic obstruction is still more advanced. The flow in the portal vein will stop and will even be reversed. The mesenteric blood will drain toward the splenic vein and then through hepatofugal collateral veins to the caval system. The contrast medium injected into the spleen will not reach the liver against the reversed flow in splenic and portal veins. This happened in 6 of the 91 cases with verified exclusive intrahepatic obstruction (Fig. 5, *A–C*). In most cases, only part of the splenic vein was filled. The visualized collateral circulation which drained the splenic area was entirely hepatofugal and in most cases consisted of vessels draining into the left renal vein. In such cases, therefore, the intrahepatic nature of the disease may easily be overlooked, even if the hepatofugal type of collateral circulation suggests such a location.

Of the second group consisting of 19 cases with proved extrahepatic occlusion with a normal liver, in 3 patients the obstruction was located in the splenic vein; in 12, in the portal vein; and in 4, both the splenic and the portal veins were found to be occluded.

In 2 of the 3 cases with splenic vein obstruction, splenoportography showed the

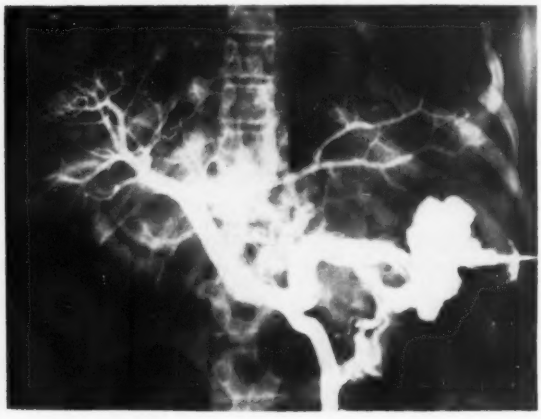

Fig. 2. Intrahepatic obstruction. Hepatofugal collateral circulation is mostly in a caudal direction via the inferior mesenteric vein.

Fig. 3. Intrahepatic obstruction. The collateral circulation utilizes exclusively the parumbilical vein.

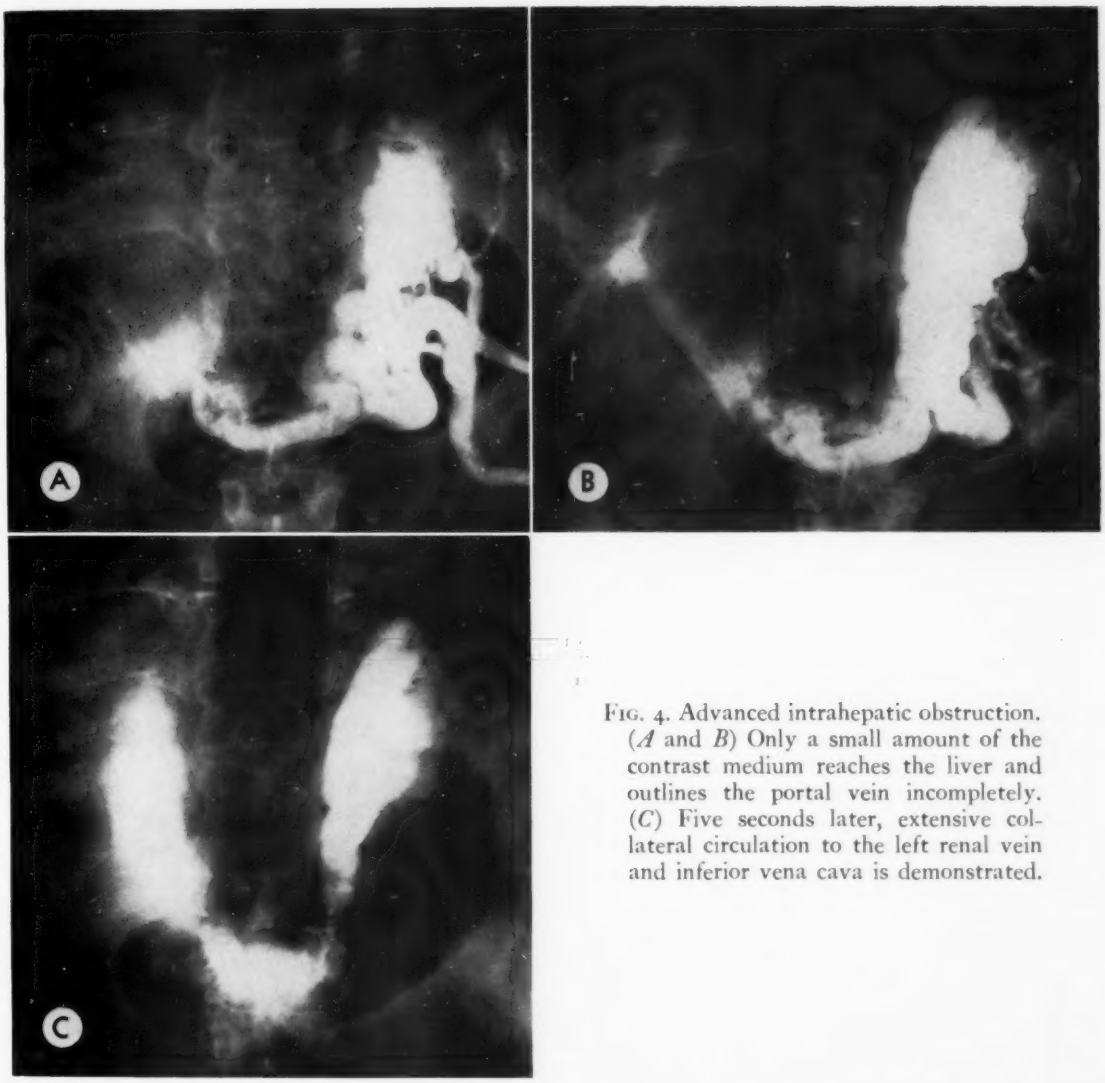

Fig. 4. Advanced intrahepatic obstruction. (*A* and *B*) Only a small amount of the contrast medium reaches the liver and outlines the portal vein incompletely. (*C*) Five seconds later, extensive collateral circulation to the left renal vein and inferior vena cava is demonstrated.

obstructed splenic vein being bypassed by hepatopetal collateral vessels draining into the portal vein, which appeared to be normal as did the liver (Fig. 6). In such cases, therefore, splenoportography clearly outlines the site of the vascular obstruction. In the third case with splenic obstruction, there was neither visualization of the splenic or portal vein nor of any hepatopetal collateral circulation. The demonstrated collateral circulation was hepatofugal, mainly directed toward the left renal vein (Fig. 7, *A* and *B*). The patent portal vein was demonstrated later by portography during laparotomy. This case, therefore, is an example of instances where both the extent of splenoportal visualization and the type of collateral circulation, as shown by splenoportography, are misleading. The correct diagnosis in such a case can only be arrived at by additional portograms and pressure measurements during laparotomy.

In most of the 12 cases of extrahepatic portal obstruction, splenoportography led to the correct diagnosis, with visualization of the splenic vein and hepatopetal collateral circulation past the obstructed portal vein to the liver (Fig. 8). However, in 2 of the 12 cases with extrahepatic portal obstruction, the splenic vein was not filled

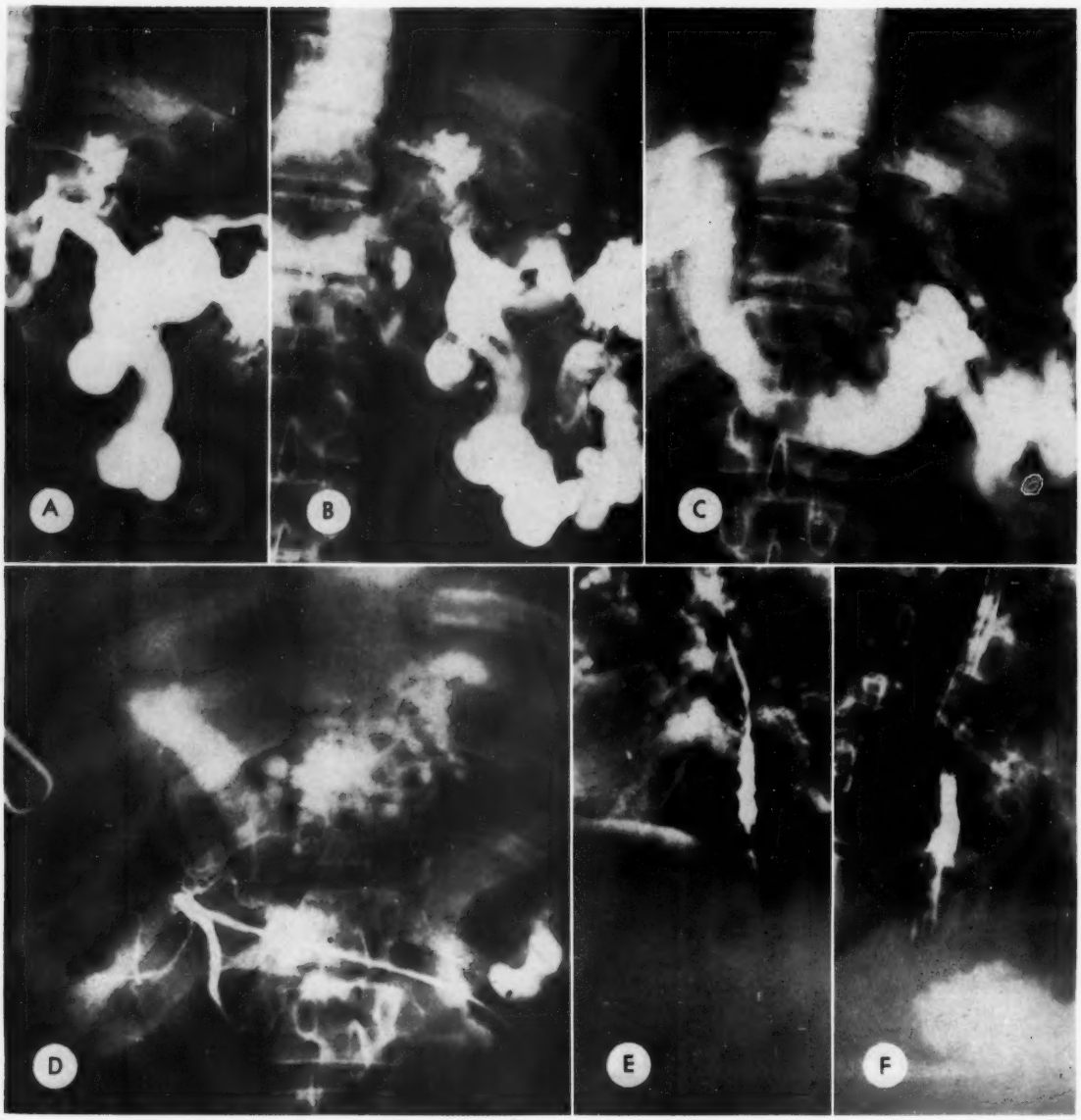

FIG. 5. Advanced intrahepatic obstruction. (*A*, *B* and *C*) The contrast medium entirely fills a tortuous collateral vessel draining the beginning of the splenic vein into the left renal vein and inferior vena cava. (*D*) Roentgenogram taken after injection of contrast medium into the superior mesenteric vein. The coronary vein responsible for the esophageal varices is now filled, as well as the patent portal and splenic veins. (*E* and *F*) Esophageal varices, not shown on the splenoportogram.

by contrast material during splenoportography, though it was found to be patent during laparotomy (Fig. 9, *A*, *B* and *C*). The nonfilling of the patent splenic vein during splenoportography in these cases is certainly due to reversed splenic vein flow. The presence of esophageal varices, as shown on esophagograms but not revealed by splenoportography (Fig. 9, *D* and *E*), indicates that the patent splenic vein is drained by some other nonvisualized collateral vessel.

In 3 of these 12 cases with extrahepatic portal obstruction, the splenic vein was visualized but there was no hepatopetal collateral circulation demonstrated (Fig. 10). This wrongly indicates an intrahepatic obstruction and is possibly due to incom-

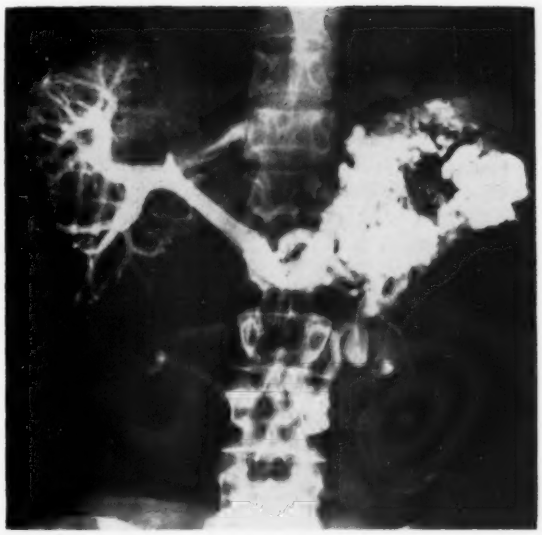

Fig. 6. Splenic vein obstruction. There is hepatopetal collateral circulation via the gastroepiploic veins and the short gastric veins to the coronary vein by which the congested area is drained into the portal vein and to the normal liver.

plete filling of the hepatopetal collaterals.

In the 4 of the 19 cases with extrahepatic obstruction where both splenic and portal veins were found to be occluded, splenoportograms showed the correct location of the obstruction by the absence of contrast medium in the splenic and portal veins and the presence of a hepatopetal collateral circulation (Fig. 11, *A* and *B*).

CONCLUSION

The presented material shows that splenoportography in most cases can reveal the correct location of any occlusion. In 85 of 91 cases with intrahepatic obstruction and in 12 of 19 cases with extrahepatic obstruction, the correct diagnosis could be made. A splenoportogram with visualization of splenic and portal veins and no hepatopetal collateral circulation (Fig. 12) definitely indicates an intrahepatic obstruction. A splenoportogram with visualization only of the portal vein via hepatopetal collateral circulation (Fig. 13) is proof of splenic vein obstruction. A splenoportogram with contrast filling of the splenic vein, nonvisualization of the portal vein, and hepatopetal collateral circulation (Fig. 14) definitely indicates an extrahepatic portal vein obstruction. A splenoportogram with nonfilling of both splenic and portal veins but with hepatopetal collateral circulation (Fig. 15) is diagnostic of either splenic or portal obstruction or

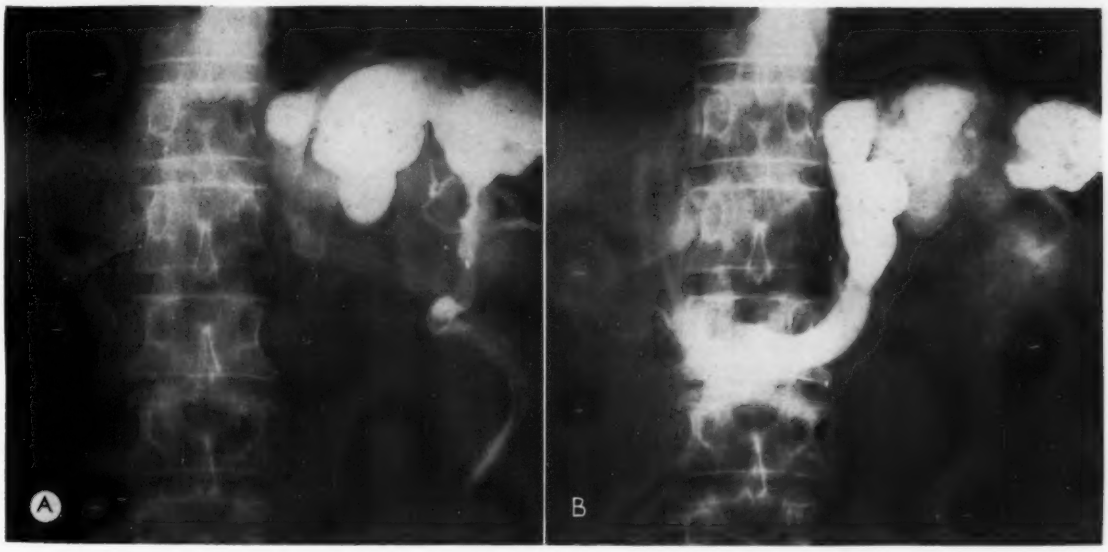

Fig. 7. Splenic vein obstruction. (*A* and *B*) There is no visualization of the splenic or portal veins and entirely hepatofugal collateral circulation from the short gastric veins toward the left renal vein and inferior vena cava is demonstrated. This is the same type of splenoportogram that is seen in some cases of intrahepatic obstruction (Fig. 5, *A*, *B* and *C*).

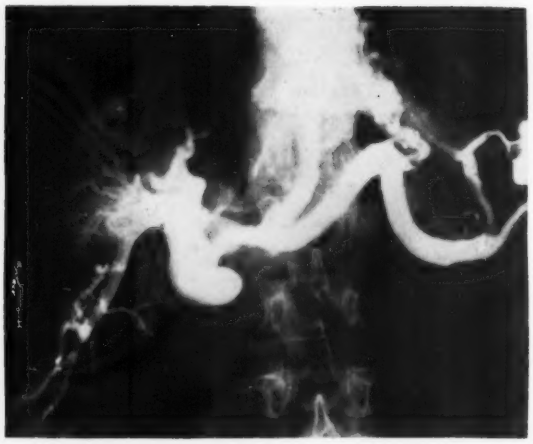

Fig. 8. Extrahepatic portal vein obstruction. The splenic vein is patent. The contrast medium bypasses the portal vein via a wide collateral vessel through the bed of the gallbladder and empties into an intrahepatic portal vein via the patent splenic vein. In addition to the hepatopetal collateral vessel, there are also hepatofugal collateral vessels—coronary vein and short gastric veins.

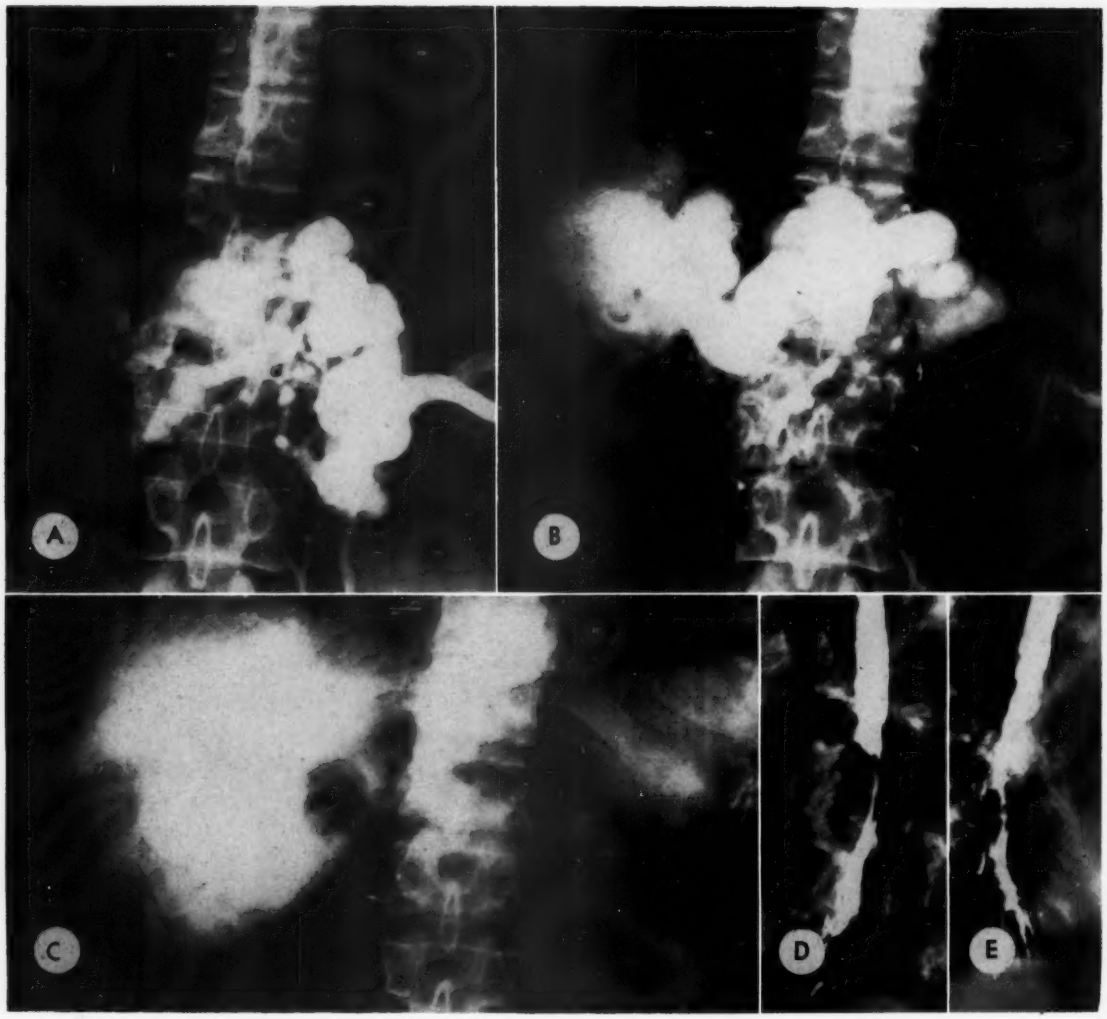

Fig. 9. Extrahepatic portal vein obstruction. (*A* and *B*) Neither the splenic nor the portal vein is outlined. (*C*) The extrahepatic location of the obstruction is shown by the hepatopetal collateral circulation through which the liver parenchyma is loaded with contrast medium. (*D* and *E*) Esophageal varices which are not shown on the splenoportogram.

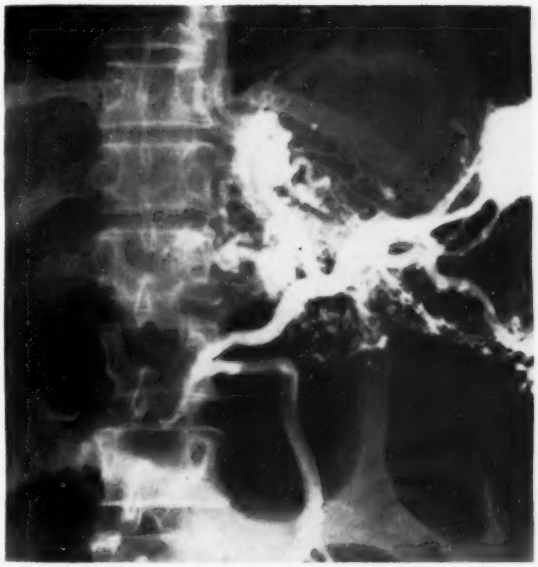

Fig. 10. Extrahepatic portal vein obstruction. The splenic vein is visualized to about the level of the obstruction. Only hepatofugal collateral vessels are filled (short gastric veins, coronary vein, inferior mesenteric vein).

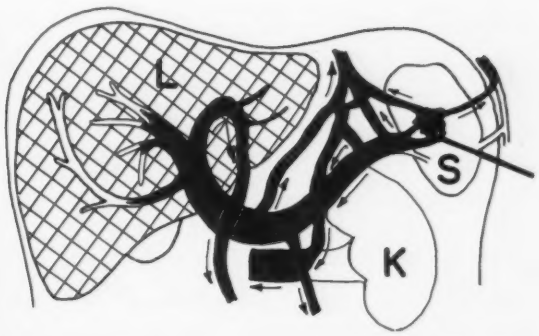

Fig. 12. Diagram of a splenoportogram indicating intrahepatic obstruction (cirrhosis). The main types of hepatofugal collateral vessels are delineated. (K = kidney; L = liver; S = spleen.)

both. However, any intrahepatic obstruction can be ruled out by this type of splenoportogram.

A splenoportogram with nonfilling of the splenic and portal veins and only hepatofugal collateral circulation (Fig. 16) indicates the presence of an occlusion but does not reveal its location. Such a finding may be caused by a severe intrahepatic obstruction and a reversed flow in the portal and splenic veins but may also be caused by a portal or splenic obstruction or by a combination of both. This type of splenoportogram was observed in less than 10 per cent of the cases in the presented material. Further examinations during laparotomy are necessary in such cases if severe diagnostic errors are to be avoided.

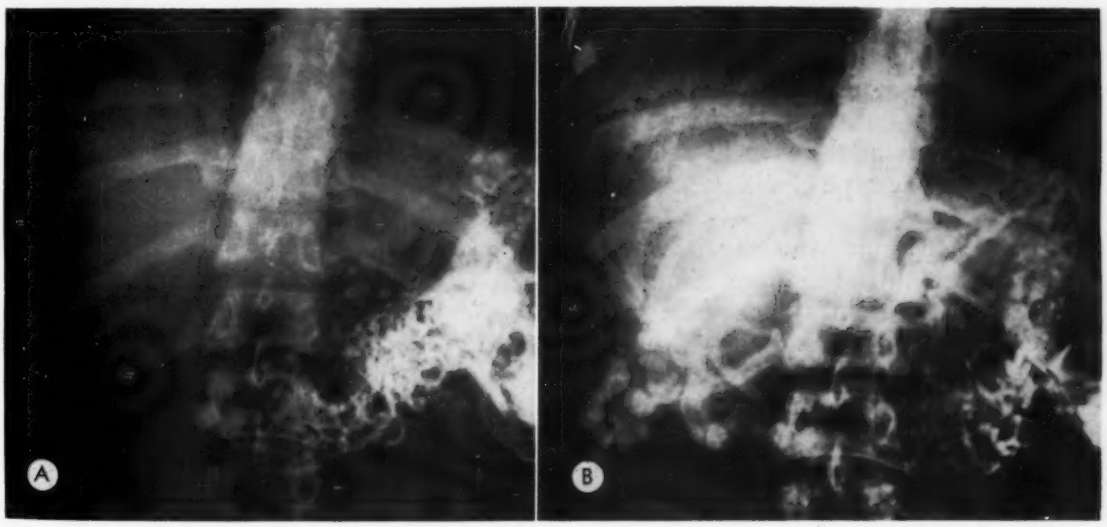

Fig. 11. Extrahepatic portal and splenic vein obstruction. (*A* and *B*) There is no visualization of the splenic and portal veins. Numerous small hepatopetal collateral vessels, difficult to distinguish but predominantly emptying in the region of the gallbladder causing filling of intrahepatic portal veins, are seen.

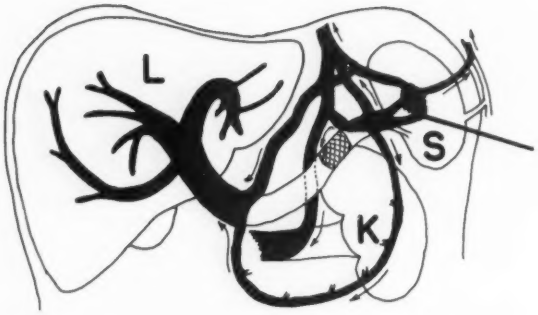

Fig. 13. Diagram of a splenoportogram indicating extrahepatic splenic vein obstruction.

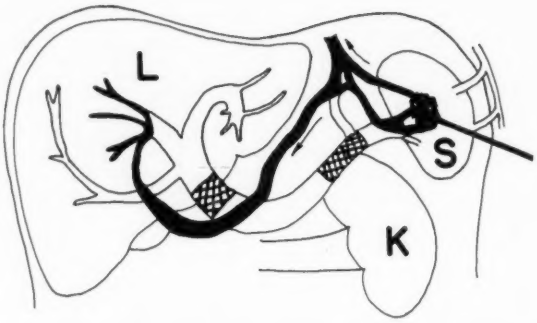

Fig. 15. Diagram of a splenoportogram indicating extrahepatic obstruction (splenic, or portal, or both).

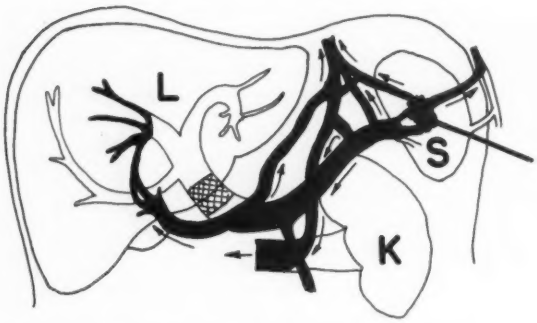

Fig. 14. Diagram of a splenoportogram indicating extrahepatic portal vein obstruction.

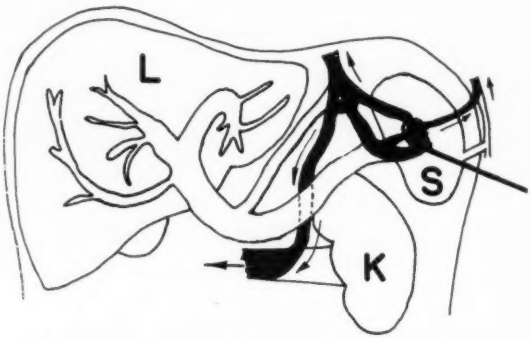

Fig. 16. Diagram of a splenoportogram which does not indicate the site of obstruction (extrahepatic or intrahepatic obstruction).

SUMMARY

With splenoportography, the presence of a portal obstruction is demonstrated by the filling of collateral vessels which are not filled on studies of normal subjects. The site of obstruction is indicated by the visualized portions of the splenic and portal veins and by the type of collateral circulation.

Splenoportograms in cases with verified intrahepatic obstruction are shown and compared with findings in cases with verified extrahepatic obstruction. The possibilities of differentiating intrahepatic from extrahepatic obstruction with splenoportography are discussed, as well as the limitations of the method.

Department of Radiology
University of Lund
Lund, Sweden

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RENAL ANGIOGRAPHY IN THE EVALUATION OF HYPERTENSION*

A COMPARATIVE STUDY OF THE VALUE OF RENAL ARTERIOGRAPHY AND DIFFERENTIAL RENAL FUNCTION STUDIES

By ERICH K. LANG, M.D.
BALTIMORE, MARYLAND

THE medical evaluation and pharmaceutical treatment of hypertension has long presented vexing problems to the clinician. Even in the early literature efforts to classify hypertension by its associated clinical manifestations and its response to treatment were made. The importance of renal artery stenosis as an etiologic factor in one of the subgroups of hypertension was first pointed out by Goldblatt *et al.*[13] in their classic paper on experimental hypertension produced by partial occlusion of the renal artery. Recent advances in vascular surgery have focused attention on this entity, since hypertension can be alleviated by surgical correction of the stenosis or by removal of the offending kidney.[1,2,6,12,16,21,22,23] Renal artery stenosis is now being recognized as a common cause of hypertension. It is therefore necessary to define strict diagnostic criteria in order to select patients amenable to surgical correction.[1] Accurate preoperative anatomic localization of the lesion will, of course, decrease the morbidity of the surgical procedure. This can best be done by renal arteriography.

The clinical features of renal hypertension are rather variable. The age and sex incidence shows a widespread distribution with probable predominance in the older age group. A familial history and past history of associated widespread arterial disease may often be elicited. Hypertensive retinopathy is commonly encountered in longstanding renal hypertension. Laboratory studies for proteinuria, hypokalemia, elevation of the blood urea nitrogen level, and decreased concentration power of the kidney only reflect longstanding and severe disease. The only characteristic physical finding is a bruit that may be heard over the midabdomen, caused by atheromatous plaques situated in the renal artery.

Differential renal function studies are the most helpful clinical laboratory examinations. These tests are based on the observation of Mueller *et al.*,[19] who noted a decrease in the urine volume and sodium concentration of the kidney with a narrowed artery, in comparison to the normal kidney of the opposite side. Howard and his co-workers[3,4,16] substantiated these findings and reported similar results in patients with proved stenosis of the renal artery. There is also an increased urinary concentration of inulin, creatinine and PAH resulting from the increased reabsorption of water by the affected kidney.[1] The diagnostic interpretation of these studies, however, relies on a comparison of the urine from the normal to that of the abnormal kidney. The limitations of these tests are self evident. Involvement of both kidneys deprives the investigator of the necessary comparison to a normal value. Conversely, involvement of only a very small segment of the kidney may not be reflected by either a detectable change in the urinary sodium concentration or volume. Furthermore, the segment supplied by the stenotic or occluded artery may not produce any urine at all and thus defy detection by analysis of the composite urine collected from this side.

I^{131} diodrast uptake studies similarly re-

* From the Department of Radiology, Johns Hopkins University and Hospital, Baltimore, Maryland.
Presented at the Sixty-first Annual Meeting of the American Roentgen Ray Society, Atlantic City, New Jersey, September 27–30, 1960.

flect renal plasma flow. These studies are particularly well suited for the investigation of bilateral diffuse arteriolar disease, which is characterized by a slow uptake curve of radioactive material.

Renal function studies, while extremely helpful in the determination of the type of hypertension, fail to anatomically localize the lesion; roentgenologic examinations, on the other hand, are designed to make such location possible.

ROENTGENOLOGIC TECHNIQUES

One of the classic findings of Goldblatt *et al.*[13] was that of the disparity in the size of the normal and the affected kidney. Usually, the size and contour of the kidneys can be estimated on plain roentgenograms of the abdomen. Intravenous pyelography facilitates the task of outlining the kidneys and comparing their relative sizes.[15,25] The concentration of the contrast medium in the pelvicalyceal system as demonstrated on the excretory urogram is not, however, an adequate measure of kidney function since the concentration of sodium diatrizoate (sodium hypaque) in the kidney pelvis parallels that of inulin and the density of the medium in the affected kidney pelvis may therefore appear increased.[9,10] The most decisive examination is direct visualization of the renal arteries. Three major techniques have been developed for this particular purpose.

Translumbar aortography has been successfully employed in the demonstration of renal arteries for many years.[5,6,11,17,18,21,22,23,25] Various modifications of this technique have been developed so as to improve the concentration of the medium and visualization of the renal arteries. Poutasse and Dustan[23] advocate a translumbar double needle technique for facilitating a rapid injection of contrast medium. One of the major shortcomings of the translumbar technique is the chance element of mixing, which may occasionally result in a pattern of contrast material imitating an obstructive arterial lesion. Nonfilling of accessory renal arteries arising proximal to the puncture site is another common source of error.

Various catheter techniques have been specifically designed to either obtain a homogeneous admixture of contrast medium and blood or to selectively inject each renal artery.[7,8,24] The "flushing technique" utilizes a large lumen catheter with multiple side holes, placed considerably above the level of the renal arteries to allow proper admixture of blood and contrast medium (Fig. 4). The catheter may be introduced via an arterial cut-down of the ulnar or femoral artery or via a percutaneous puncture of the femoral artery using the Seldinger technique,[8] which offers the great advantage of percutaneous introduction of a catheter without cumbersome arteriotomy and subsequent repair. Furthermore, the puncture site can be readily examined and bleeding controlled by external compression. Most of the patients reported in this series have been examined with a modified Seldinger "flushing technique," which is performed in the following manner: After adequate local anesthesia is achieved, the femoral artery is punctured percutaneously.[8,24] A highly flexible guide wire is inserted through the needle and remains in the artery after withdrawal of the needle. The wire is used as a guide over which a radiopaque polyethylene catheter is introduced into the artery. After removal of the guide wire, the catheter is advanced to the desired level, usually D-10, under fluoroscopic control. In addition to an end hole, the catheter is equipped with multiple side holes distributed over a segment of about 2 inches from its tip. Approximately 35 cc. of 90 per cent sodium diatrizoate (sodium hypaque) is then injected under a pressure of about 120 pounds per square inch. To decrease the viscosity, the medium is usually prewarmed to 40° C. Serial roentgenograms are obtained on a Schönander automatic film changer. An exposure rate of two films per second was found to be quite adequate to assure proper documentation of all structures. For the arterial phase, a film coverage of four seconds appears to suffice. Several delayed arteriograms dem-

onstrating the nephrographic effect are desirable and are best obtained three to seven seconds after injection.[9]

Edling and his co-workers[9,10] pointed out that this nephrographic effect is due to a combination of contrast medium in the capillaries and the excreted medium in the tubules. Depending on the phase, either the cortex or the pyramids may show particularly dense staining. The absence of such a nephrographic effect suggests a decrease or absence of blood supply to the respective area.[15] The observation of a localized decreased nephrographic effect may be the only way by which to diagnose impairment of blood flow to one of the smaller tributary arteries (Table I).

Ödman[20] advocates selective engagement of the renal arteries with a catheter equipped with a specially molded tip. This maneuver, similar to the placement of a Seldinger catheter, is carried out under fluoroscopic control. For selective injections an end hole catheter is used and an amount of 5–7 cc. of 50 per cent sodium diatrizoate suffices for the demonstration of the renal artery. Nonfilling of accessory renal arteries and the fact that no comparison can be made to the normal side are the major disadvantages of this method.

TABLE I

FINDINGS IN HYPERTENSIVE PATIENTS EXAMINED BY RENAL ARTERIOGRAPHY

Total No. of Patients	54
Localized Arterial Lesions	30*
Unilateral localized arterial lesions amenable to surgery	16
Generalized Arteriosclerotic Lesions	14
Normal Renal Arteriograms	10†

* Included are two false positive arteriograms. Accessory renal arteries originating higher in the aorta failed to visualize on the first examination but were subsequently demonstrated.

† Included are two false negative arteriograms. The significant stenosis of one of several accessory renal arteries was not appreciated on the arteriogram. The decreased nephrographic effect of the supplied area should have directed attention to it. Surgical exploration yielded the correct diagnosis.

RESULTS

The early experience gained in the evaluation of renal hypertension pointed out the necessity of comprehensive medical and roentgenologic examinations in this patient group. Laboratory studies including regitin test, catacholamine levels and differential renal function studies should precede renal arteriography in an effort to eliminate other causes and establish a tentative diagnosis of renal hypertension.

In our series the final selection of patients amenable to surgical correction was made on the basis of renal arteriography. This method alone allowed a preoperative determination of the type of procedure most suitable for the particular patient. In patients with localized lesions in the main renal artery, an endarterectomy was performed (Table II, and Fig. 1 and 2). Patients with very extensive disease of the main renal artery or peripheral lesions were subjected to nephrectomy. In the case of a patient with one remaining kidney, an arteriogram showed the proximity of the

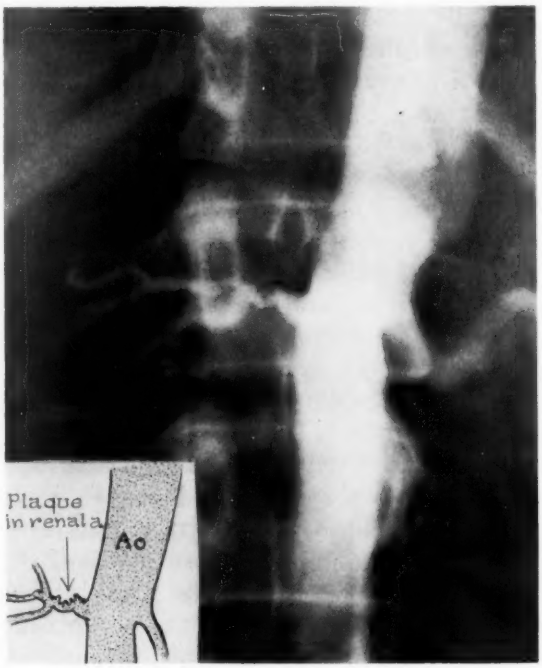

FIG. 1. The right main renal artery is narrowed by an irregular plaque near its origin.

TABLE II

STUDIES AND TREATMENT IN 13 PATIENTS WITH HYPERTENSION

Age	Sex	Clinical Data						Differential Renal Function			I^{131} Diodrast Uptake	Blood Pressure Post Stenosis	Intravenous Pyelography	Renal Arteriography		Treatment
		Blood Pressure before Treatment	Blood Pressure after Treatment	Urine Concentration	Blood Urea Nitrogen	Bromsulphalein Test	Eye Grounds	Volume	Na	Inulin			Size of Kidney	Nephrographic Effect	Findings	
40	F	182/90	170/90	D	N	N	N	D	D		D	D	N	D	Narrowing of left main artery	Endarterectomy
40	F	250/120	190/100	D	I	D	gr. 2	D	D				D	D	Plaque in left main artery	Endarterectomy
57	M	220/110	160/80	N	N	N	gr. 3	D	?	I	D	D	N	D	Plaque in right main artery	Endarterectomy
45	M	170/100	150/80	N	N	N	N	?	?				N	N	Aortic plaque with thrombus	Homograft
58	F	225/100	190/90	N	I	D	gr. 2				D	D			Plaque in left main artery	Splenorenal shunt‡
50	M	210/120	160/110	N	N	N	N	D	D	I	D	D	N	D	Normal	Splenorenal shunt
27	F	190/110	138/90	N	N	N	N	D	D		D	D	N	N	Plaque in right main artery	Nephrectomy
25	F	190/100	130/70	N	N	N	gr. 1	D	D	I	D		N	D	Plaque in right inferior pole	Nephrectomy
36	M	170/120	130/80	N	N	N	gr. 1	D	D				N	D	Plaque in right upper pole	Nephrectomy
55	M	200/140	130/80	N	N	D	gr. 1	D	N			D	D	D	Hourglass stenosis of right main artery	Nephrectomy
54	M	160/90	140/80	D	I	D		D	D		D		D	D	Stenosis of left main artery	Nephrectomy
40*	M	190/120		D	I	D	gr. 3	D	N	I	D†		N	D	Holdup of medium in arcade vessels	
46	M	190/120	190/40	N	N	N	gr. 1	D	?			N	N	N	Narrowing of right main artery	Sympathectomy

D—Decreased.
I—Increased.
N—Normal
* Arteriolosclerosis found at autopsy.
† Both sides flat uptake curve.
‡ Previous right nephrectomy.

FIG. 2. The left renal artery shows marked stenosis with post-stenotic dilatation. Note the delay in filling of the arcade vessels of the left kidney.

splenic and diseased renal artery and confirmed the feasibility of a splenorenal anastomosis.

Renal arteriograms, while usually definitive, may occasionally lead to an erroneous diagnosis. On 2 occasions accessory renal arteries arising proximal from the aorta failed to visualize because of faulty low placement of the catheter and imitated a complete obstruction of the artery supplying the anterior upper two-thirds of the kidney (Table 1). Normal differential renal function studies and a normal I^{131} diodrast uptake curve of the suspected kidney led to re-examination by arteriography and demonstration of the cause of the error. Renal arteriography performed with the translumbar technique and selective renal artery injections is particularly subject to such error (Fig. 5).

Occasionally, a stenosis of one of the segmental renal arteries may be missed in the interpretation of the arteriograms. Careful scrutiny of the delayed roentgenograms will almost certainly safeguard against such an error, since the decreased nephrographic effect of the ischemic area tends to be quite obvious. Two patients in this series were explored on a basis of differential renal function studies suggesting such a peripheral lesion. Even retrospectively, it was difficult to identify the point of arterial obstruction on the arteriogram; however, the delayed roentgenograms showed a characteristic blanching of the affected segment which should have implied the correct diagnosis (Table 1).

An excellent correlation of the functional importance of the stenosis and the degree of decrease in nephrographic effect was noted. One patient appeared to show a significant stenosis of the main renal artery on arteriograms, yet the nephrographic effect of both normal and abnormal kidney appeared to be equal. Operative pressure readings of the aorta and post-stenotic segment of the renal artery showed no marked gradient. Conversely, one patient with a rather mild narrowing of the renal artery showed a markedly decreased nephrographic effect. This observation corresponded well to a severe post-stenotic pressure drop of 240 mm. to 40 mm.

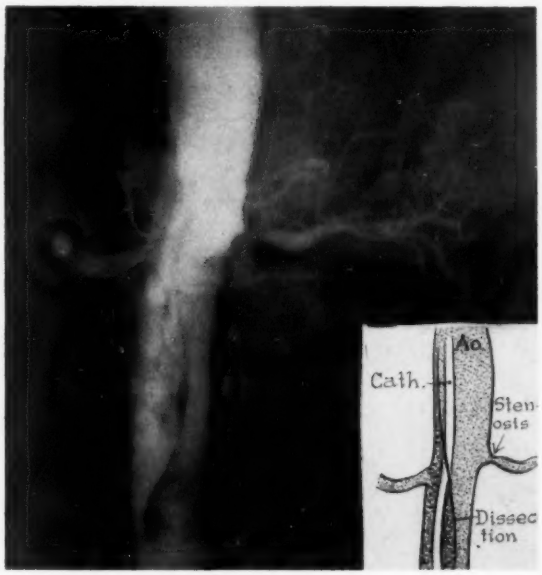

FIG. 3. The origin of the left renal artery is markedly narrowed. Observe the double contour, indicating a partial subintimal injection of contrast medium. The catheter tip is in the lumen of the aorta, therefore normal appearing transmitted pulsations were observed.

Fig. 4. An accessory renal artery supplying the lower pole arises proximal to the main renal artery. The nephrographic effect of the right kidney is decreased. The lower pole of the right kidney has been resected.

Generalized arteriolosclerotic disease also shows a markedly decreased nephrographic effect. The diagnostic characteristic of this entity, however, is the peculiar hold-up of contrast medium in the arcade vessels. In 2 proved cases the contrast material was observed to hang in these vessels for seven seconds (Table II).

An attempted correlation of the size of the kidney to the degree of arterial obstruction was disappointing. Only 25 per cent of all patients with proved renal artery lesions showed a noticeable disparity in kidney size on the excretory urogram. In 75 per cent of the cases, the intravenous pyelogram failed to reveal any abnormality of the affected kidney (Table II).

A review of the arteriograms showed 30 of 54 patients to have localized arterial lesions (Table I). However, only 16 patients had unilateral disease. All of the operated 11 patients showed excellent response and a significant drop of blood pressure. Particularly 3 patients in the younger age group showed a very dramatic return to normotension almost immediately after surgery (Table II). Lesions in the main renal artery appeared to be more easily corrected than the more peripheral lesions and showed a uniformly prompt response. A longstanding history of hypertension appeared to be no contraindication to arteriography or operative procedure. Patients with bilateral lesions or generalized arteriolosclerotic disease were treated with sympathectomy or put on a medical regimen.

Properly performed, modified Seldinger arteriography has a low percentage of morbidity. However, particular care has to be exercised to withdraw the guide wire immediately after the catheter has been introduced into the artery. Simultaneous advancing of the guide wire reinforced by the catheter may have deleterious effects. The guide wire is then sufficiently stiff to perforate the aorta or to dissect subintimally. Free arterial pulsations transmitted through the catheter do not guarantee that the entire length of the catheter is within the lumen of the aorta. The pulsations may be transmitted via only one of the openings of the catheter communicating with the aorta. In several of the earlier at-

Fig. 5. Translumbar aortogram. There is an hourglass stenosis of the origin of the artery supplying the left lower kidney pole. Note the unsatisfactory demonstration of the most proximal artery by this technique.

TABLE III

COMPLICATIONS

Total No. of Cases	54
Subintimal Injections	6*
Hematoma at Puncture Site	4

* One patient showed transient drop of hematocrit.

tempts, subintimal injections of contrast medium resulted from failure to comply with these precautions (Fig. 3). None of these subintimal injections, however, caused serious complications. Only one of the patients showed a transitory drop of the hematocrit which became stabilized after forty-eight hours without treatment (Table III).

SUMMARY

The experience in 54 hypertensive patients examined by renal arteriography with a modified Seldinger "flushing technique" is reported. Excretory urograms may show increased contrast medium concentration in the pelvis of the affected kidney secondary to increased water reabsorption by the affected kidney. The size of the kidney on excretory urograms or on plain roentgenograms of the abdomen shows poor correlation to the disease. The importance of high placement of the catheter tip to allow proper admixture of the contrast medium and visualization of all accessory renal arteries is emphasized. The decreased nephrographic effect of a small segment is an important sign of ischemia of this area. The decrease of nephrographic effect of the affected kidney showed an excellent correlation to the blood pressure gradient across the stenosis. Pulsatile pressure transmitted through the catheter does not guarantee that there has not been partial subintimal dissection or perforation with the catheter tip. Gentle handling during the advancing of the catheter with complete withdrawal of the guide wire is mandatory.

Department of Radiology
The Johns Hopkins Hospital
Baltimore 5 Maryland

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DIAGNOSIS OF CEREBRAL ATROPHY FROM THE ANTEROPOSTERIOR CAROTID PHLEBOGRAM

By A. D. SEARS, M.D., J. E. MILLER, M.D., *and* B. B. KILGORE, M.D.
DALLAS, TEXAS

RADIOLOGISTS are not generally aware that diffuse cerebral atrophy can be diagnosed with reasonable certainty from carotid angiograms, provided the deep cerebral veins are well opacified. References to arterial and venous alterations in mass lesions and other obstructive phenomena producing dilated ventricles are abundant but references to the appearance of the deep cerebral veins in brain atrophy are scant.[2,6]

The recognition of venous alterations indicating cerebral atrophy is important because of the meteoric rise in the number of cerebral angiographies performed for carotid artery disease. The ability to diagnose cerebral atrophy further extends the usefulness of angiography since the recognition of either or both of these disease processes will make unnecessary untold numbers of air studies on aged patients who might suffer financial and physical hardship by undergoing multiple diagnostic procedures. The frequent association of these two diseases, as noted by Keirns and Whiteleather,[1] is apparently more than coincidental and later studies may well show carotid insufficiency to be a major factor in producing cerebral atrophy in the older patient.

TECHNIQUE

Biplane angiography is performed in our department on Schönander units. A needle is inserted percutaneously in each common carotid artery below the carotid bifurcation and successive injections of 10–15 cc. of 50 per cent hypaque are made, pausing only to change magazines between injections (four magazines being used for the entire procedure). The number of angiograms taken in each plane varies with the neurosurgeon. An average of five films in each plane are usually exposed per side for a total of twenty films.

ANATOMY

The anatomy of the deep cerebral veins has been well described by numerous authors. The line drawings published by Wolf *et al.*[6] of the normal deep venous channels and their altered appearance with variations in positioning are helpful (Fig. 1). Briefly, referring to Figure 1, the "venous angle" which approximates the foramen of Munro is situated at the junction of the vein of the septum pellucidum (S.V.) and the thalamostriate vein (T.S.) with the internal cerebral vein (I.C.V.). Manifold variations between these veins and those of the caudate nucleus occur. The thalamostriate and caudate veins (C.V.) are responsible for the definition of the outer wall of the lateral ventricle in its central portion overlying the thalamus. The internal cerebral veins, roughly 2 mm. from the midline on each side, course posteriorly in the tela choroidea above the third ventricle. These veins, seen on end, constitute the "headlight," a sensitive indicator of mass lesions in the anterior half of the brain. These veins join with the basal veins (B.V.R.) on either side to form the midline vein of Galen which delineates the splenium of the corpus callosum in coursing upward to enter the straight sinus.

Several variations in the appearance of the thalamostriate and caudate veins relative to the venous angle have also been described.[3,4] These are of importance in the accurate analysis of small adjacent neoplasms but are of no significance in the diagnosis of atrophy, since delineation of the size of the lateral ventricle is less exacting.

DISCUSSION

In order to diagnose diffuse cerebral atrophy, one must be able to recognize ventricular dilatation. For this purpose we, unlike others,[2] depend on the anteroposte-

rior half axial phlebogram rather than the lateral view.

In Figure 2*A*, tracings demonstrate that, in normal cases, there is a characteristic medially directed convexity to the thalamostriate vein as it courses anteriorly and medially over the thalamus to join the internal cerebral vein. Air studies on both normal and abnormal cases are dotted in for comparison. Those cases without air studies are included because they are so typical of their category. One will readily

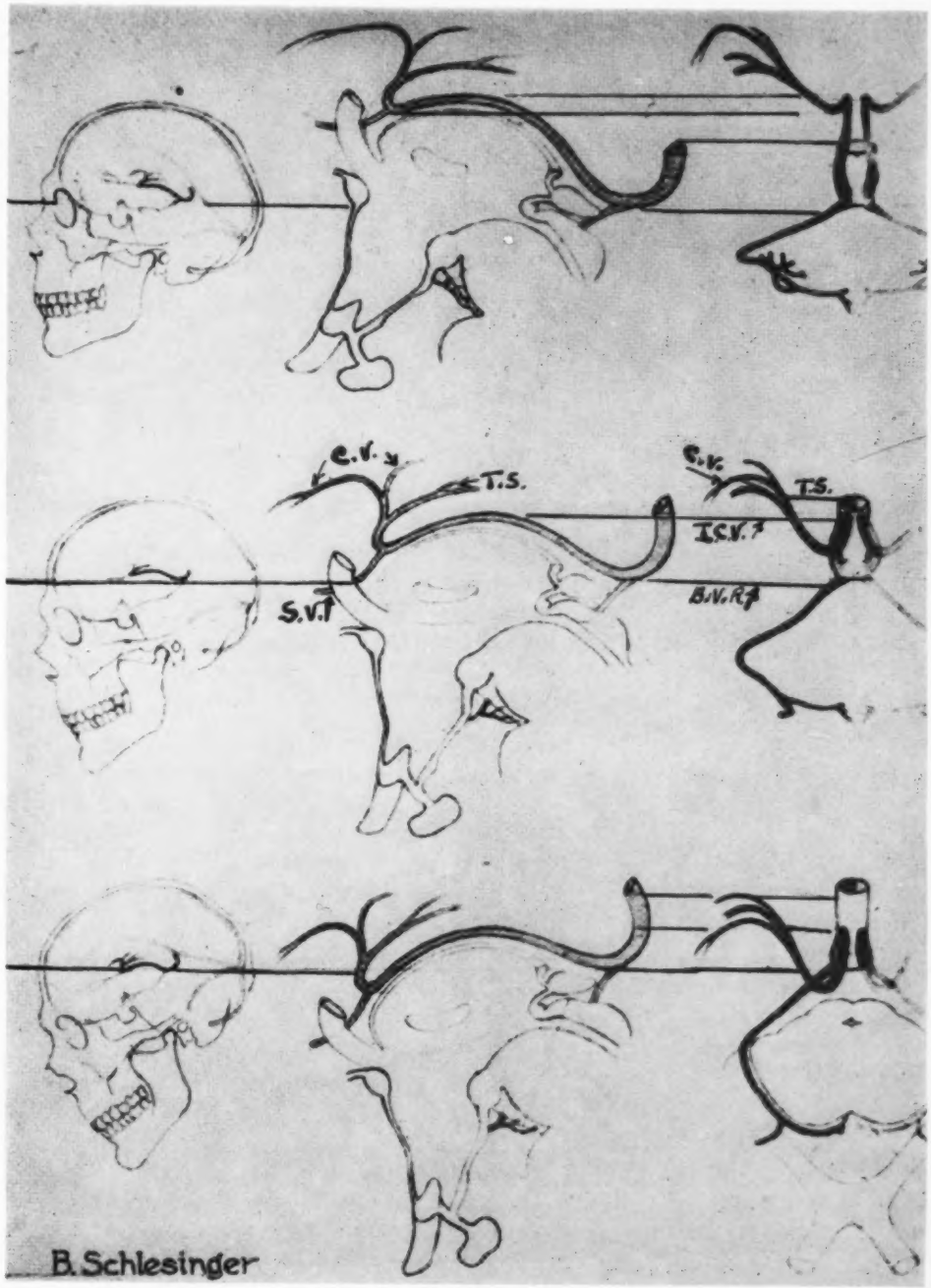
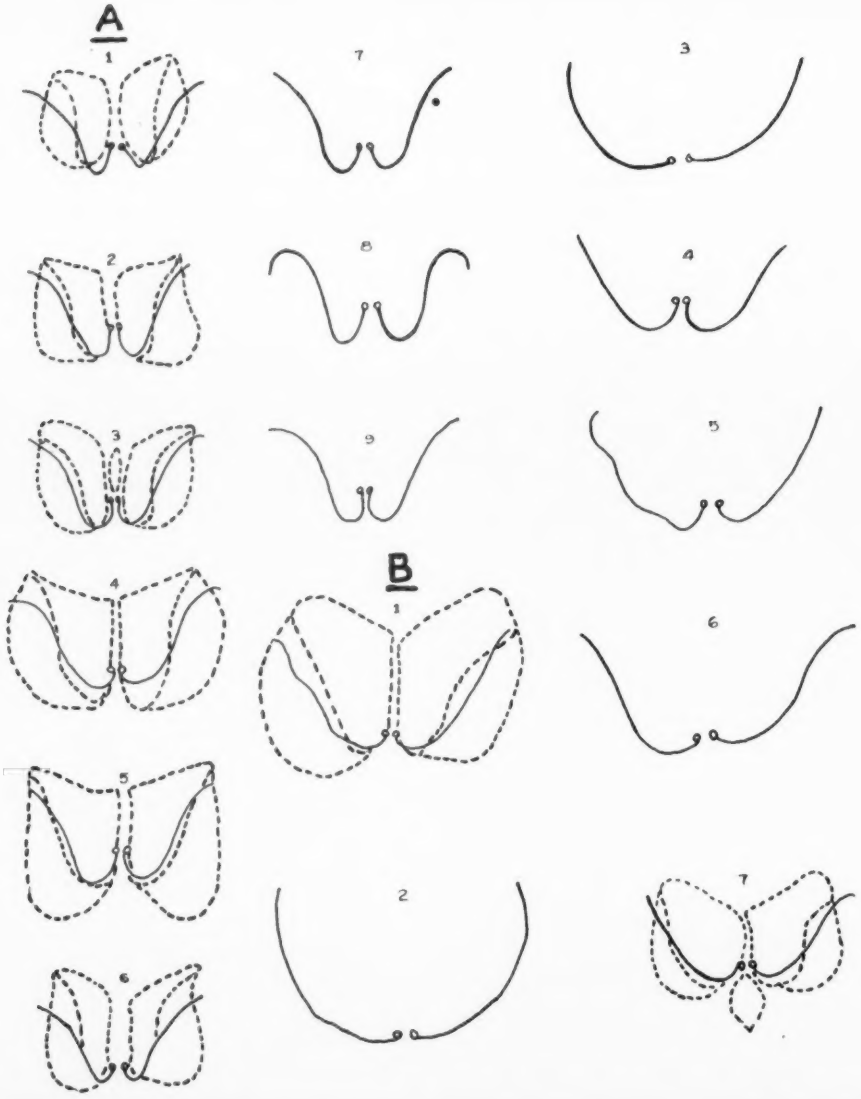


Fig. 1. Line drawings of the deep cerebral veins in anteroposterior projections with different head tilts. Transverse lines connect the same reference points on the lateral views. (By permission of *Radiology*.[6])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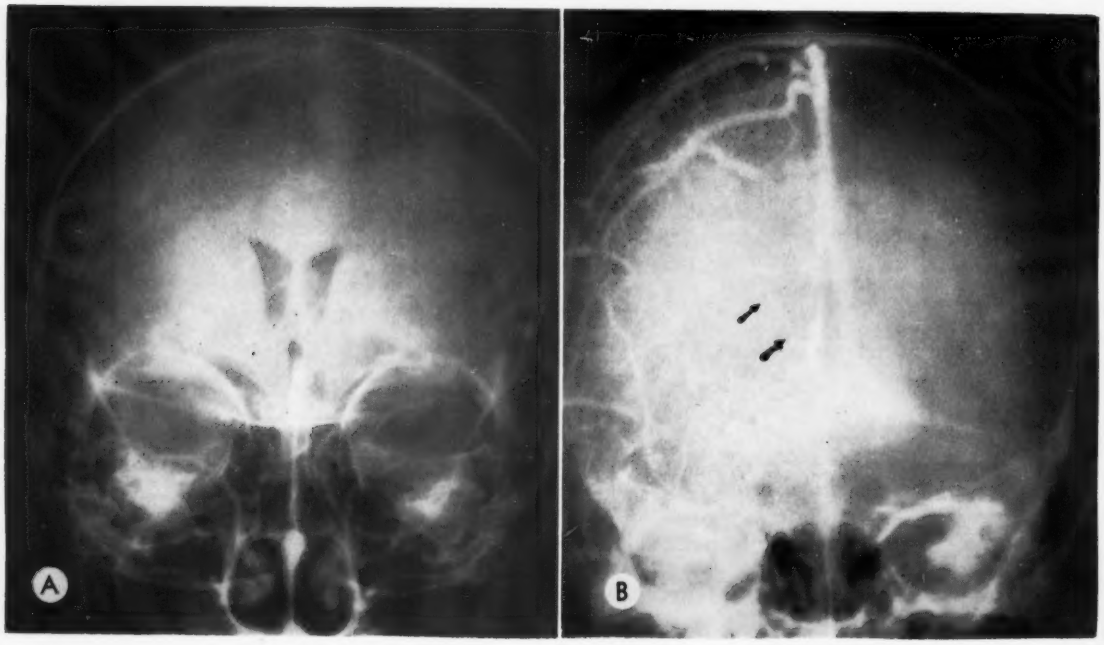
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Fig. 2. Demonstration of the close correlation between the thalamostriate vein and the ventricular outline laterally in the anteroposterior projection. (*A*, 1–9) Tracings of normal phlebograms with (dotted lines) and without associated air studies. (*B*, 1–7) Tracings of abnormal phlebograms with (dotted lines) and without associated air studies showing various degrees of atrophy. Those without air studies are included because they are considered typical.

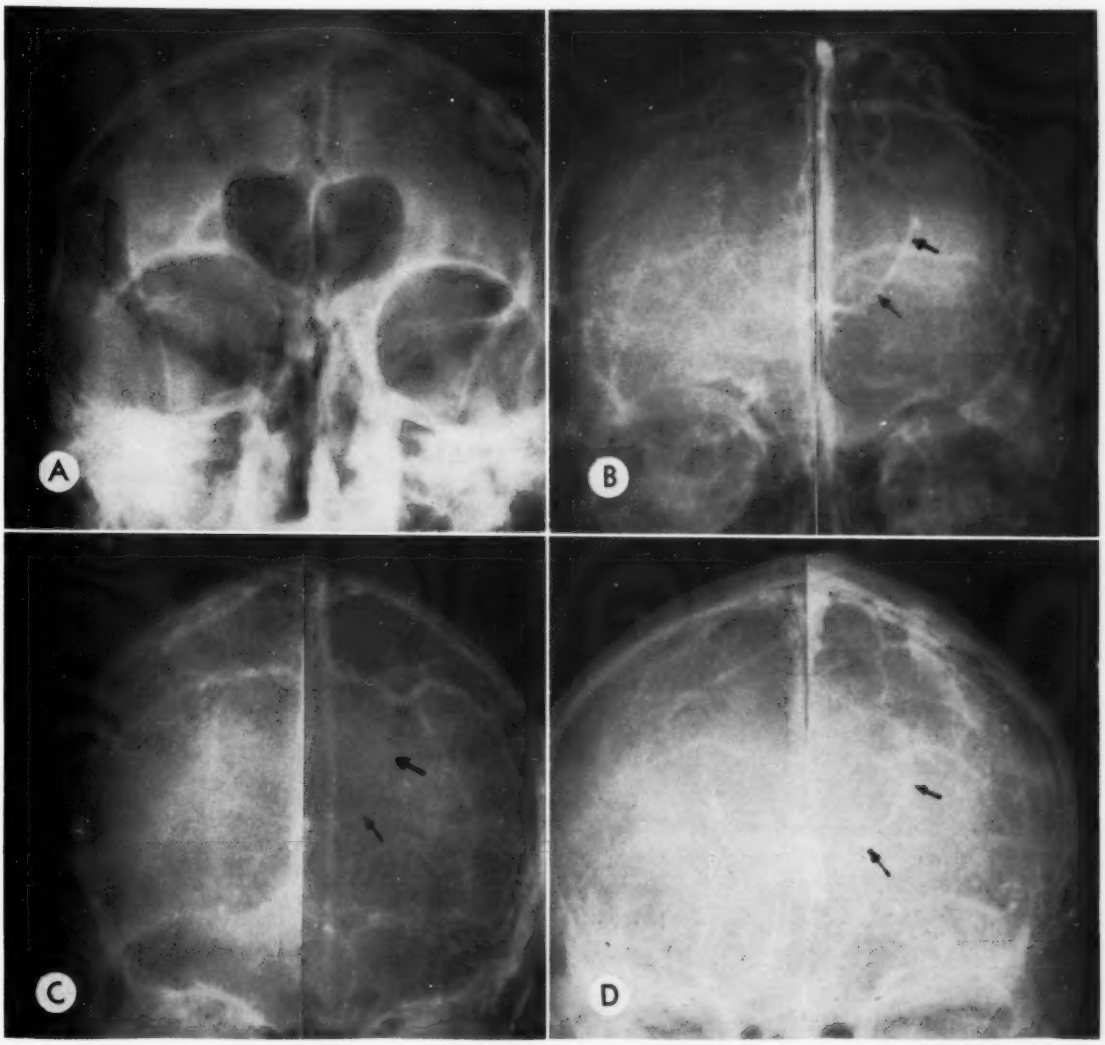

Fig. 4. (*A*) Abnormal pneumoencephalogram and (*B*) phlebogram on the same patient showing dilated lateral ventricles. (*C* and *D*) Phlebograms showing equally abnormal venous alterations. Air studies were not done on these 2 patients. In *B*, *C* and *D*, right and left injection phlebograms were split and joined to demonstrate the "short horn" appearance in atrophy.

Fig. 3. (*A*) Normal pneumoencephalogram and (*B*) phlebogram on the same patient. Arrows indicate the thalamostriate vein, corresponding to the outer wall of the lateral ventricle. (There was an incidental finding of a cyst in the septum pellucidum.)

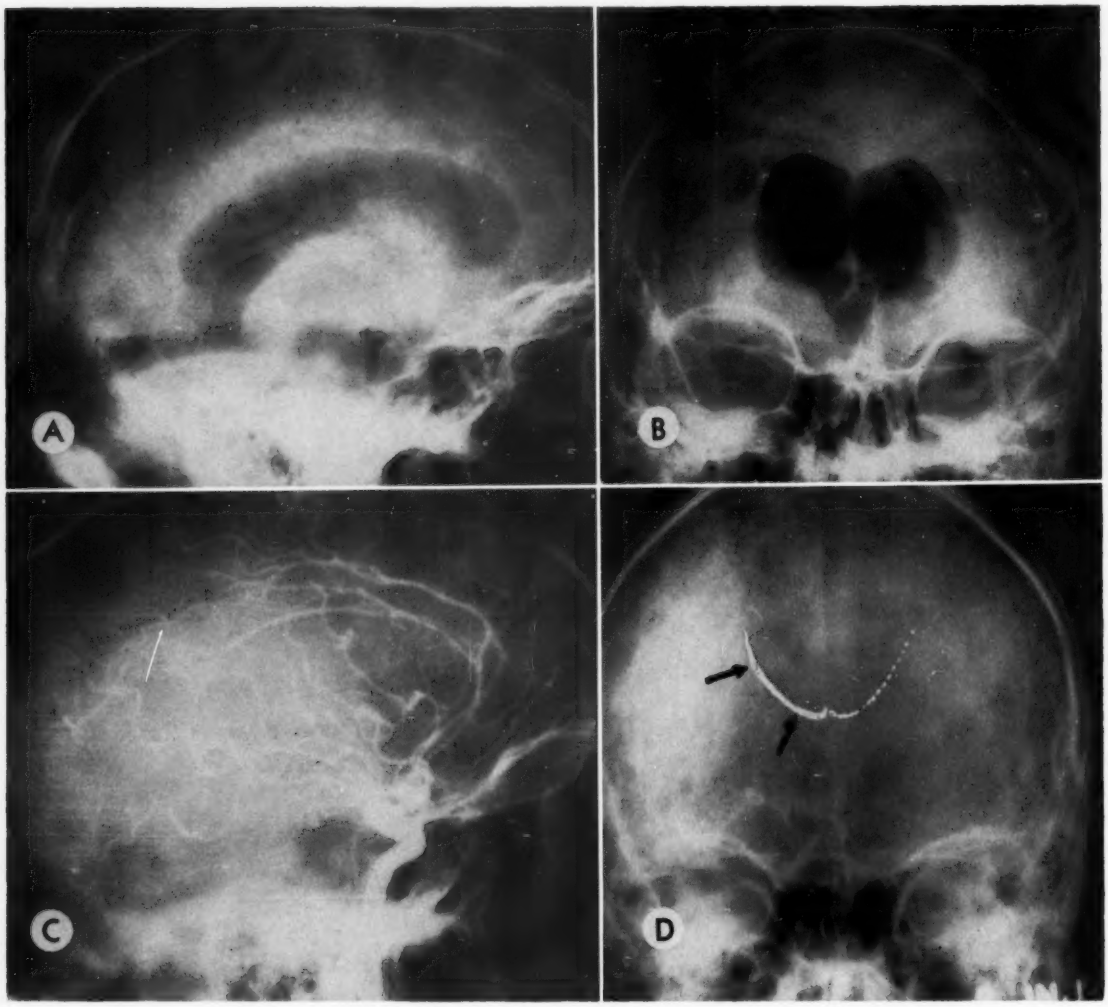

FIG. 5. (*A* and *B*) Pneumoencephalograms showing dilatation of the ventricles. (*C* and *D*) Arterial and venous changes indicating that the dilated ventricles are due to increased pressure. Note the stretched and "streaming" appearance of the arteries in *C*. (The veins in *D* have been retouched.)

note that, in the cases of atrophy (Fig. 2*B*), the curve of the thalamostriate vein is greatly widened and is reversed from that of the normal cases, being convex laterally. This results from the enlargement of the lateral ventricles due to loss of brain substance and flattening of the normally curving surfaces of the basal ganglia and thalamus.

A normal pneumoencephalogram and phlebogram on the same patient show an excellent correlation of ventricular size to the deep venous structures (Fig. 3, *A* and *B*).

In many instances, we have also been impressed by the clarity with which the lateral ventricles stand out as negative shadows against the opacified brain substance during the capillary phase, or on the "cerebrogram." This is especially noticeable with 12–15 cc. injections of hypaque. On occasion, this may be useful when the full phlebogram is not obtained for some technical reason. With practice, the exclusion of ventricular dilatation becomes easier than its recognition.

Roentgen studies of 3 cases of atrophy (Fig. 4, *A–D*), one accompanied by an air study, demonstrate the typical abnormal

appearance of the thalamostriate vein shown diagrammatically in Figure 2*B*. It is interesting to note that, by combining split phlebograms of the venous phases on the injected sides, there is a startling resemblance to a pair of short horns. Moderate to severe atrophy may be suggested when this appearance is present.

One must distinguish between dilated lateral ventricles due to increased intracranial pressure as opposed to atrophy. This is easily done by studying the arterial phase, which will show stretched and compressed arteries when the dilatation is due to pressure (Fig. 5, *C–D*). The lenticulostriate arteries also show lateral stretching, whereas little if any deformity of these arteries is apparent in atrophy. In some instances of atrophy, the major arteries, conversely, may present a sagged appearance.

We have been unable to obtain as close correlation between a large group of angiograms and air studies as we would have liked because of the understandable reluctance of the neurosurgeon to perform multiple diagnostic procedures once abnormalities amenable to surgery have been excluded. It is hoped that others may amplify our impression of the usefulness of carotid angiography in the diagnosis of cerebral atrophy.

CONCLUSIONS

1. Enlargment of the lateral ventricles accompanying cerebral atrophy can be easily distinguished on the anteroposterior carotid phlebogram.

2. Recognition of this possibility further extends the usefulness of cerebral angiography and may effect an appreciable decrease in the number of difficult diagnostic procedures on aged, infirm, and economically handicapped patients.

A. D. Sears, M.D.
Department of Radiology
Baylor University Medical Center
3500 Gaston Avenue
Dallas, Texas

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ROENTGENOLOGIC IDENTIFICATION OF A LEFT CEREBELLAR HEMANGIOBLASTOMA BY MEANS OF RIGHT CAROTID ANGIOGRAPHY*

By BERNARD S. EPSTEIN, M.D.
NEW HYDE PARK, NEW YORK

CEREBELLAR tumors often may be accurately identified on vertebral angiograms. However, the demonstration of such a neoplasm by carotid angiography done on the contralateral side is uncommon. The case reported here correlates an anatomic variation in the circle of Willis and passage of contrast medium from the right carotid artery into the left superior cerebellar artery.

REPORT OF A CASE

H.J., a fifty-one year old man, had complained of occipital headaches unrelieved by aspirin of three months' duration, anorexia followed by projectile vomiting, and some difficulty in walking which had become a staggering gait, broad-based during the past month. A brief fainting episode occurred about one month before admission. Weakness in the right leg was noted two weeks later. On several occasions he had lost his equilibrium, falling towards the left side. A feeling of thickness of the tongue and occasional difficulty in speaking was noted. He had lost 30 pounds since the onset of his illness. There were no convulsive episodes, visual loss, tinnitus or personality changes.

On physical examination the patient was somewhat lethargic. Bilateral papilledema, fundal hemorrhages and venous engorgement were present. No proprioceptive or vibratory sense changes were noted. The heel to toe and finger to nose tests were normal. The Romberg sign was negative. Some adiadochokinesis was noted in the left hand. The cerebrospinal fluid examination was not remarkable.

Electroencephalographic examination was reported as abnormal, with severe diffuse dysfunction and focal accentuation at the right parieto-occipital area.

Plain roentgenograms of the skull showed no bony defects in the vault. The sella turcica was normal in size, with definite demineralization of its dorsum. The pineal body was not displaced from its usual position in the frontal or lateral projections.

Right lateral percutaneous cerebral angiography, with 12 exposures over six seconds, after injection of 8 cc. of 50 per cent hypaque, revealed the anterior cerebral artery to be moderately elevated (Fig. 1*A*). The middle cerebral vessels were not displaced. The posterior cerebral and the superior cerebellar arteries filled well by way of a large anomalous trunk from the upper portion of the carotid system. Some contrast medium refluxed down into the basilar artery for a distance of approximately 2 cm. on the first two angiograms in the series. The basilar artery was in close approximation to the demineralized dorsum sellae. The venous phases disclosed a small hypaque stain deep in the posterior fossa approximately at the level of the internal auditory meatus at a point 5.5 cm. from the clivus (Fig. 1*B*).

On a similar examination, the anteroposterior projection with the head in the Chamberlain-Towne position, the anterior cerebral and middle cerebral vessels were normal. Both posterior cerebral arteries filled simultaneously (Fig. 1*C*). During the venous phase a tumor stain about 1.5 cm. in diameter became evident in the left posterior fossa about 3.5 cm. from the midline (Fig. 1*D*).

Left percutaneous cerebral angiography showed the left carotid syphon to be normal (Fig. 1*E*). The anterior cerebral artery was bowed upward. The left middle cerebral artery was normal. Inasmuch as the contrast material did not enter the left posterior cerebral vessels, the tumor stain was not present on this examination.

Because of the electroencephalographic demonstration of a right parieto-occipital focus, lumbar pneumoencephalography was done. A small amount of air entered the lateral ventricle. The cisterna pontis was narrowed, meas-

* From the Department of Radiology, The Long Island Jewish Hospital, New Hyde Park, New York.

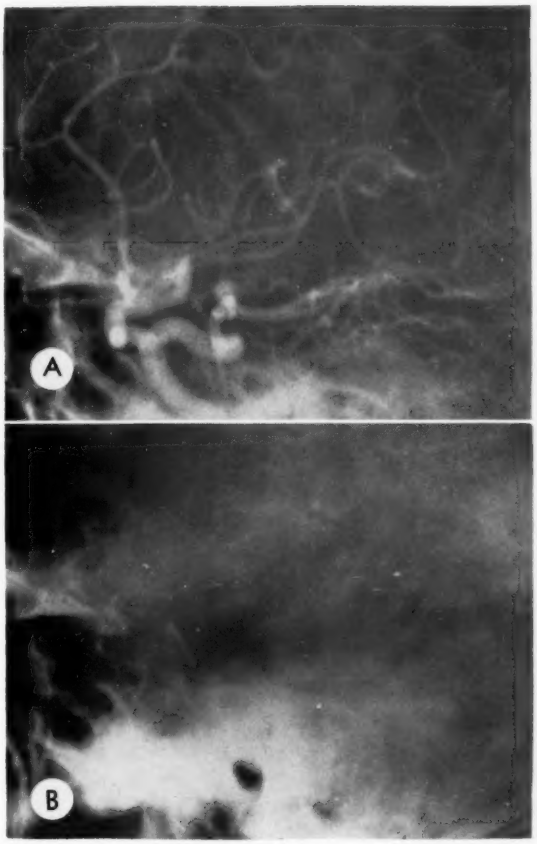

Fig. 1. (*A*) Percutaneous right cerebral angiogram demonstrating a large anomalous vessel emerging from the syphon and supplying both posterior cerebral and superior cerebellar arteries. Several small vessels can be seen directed towards the superior aspect of the cerebellum. (*B*) Late venous phase of the same carotid angiography. A tumor stain can be identified behind the mastoid bone. The stain is roughly ovoid in appearance and measures 1.5×1 cm.

uring about 0.3 mm. The fourth ventricle was poorly filled. The proximal portion of the aqueduct of Sylvius was sharply angulated anteriorly. After 25 cc. of air had been injected, the patient had a generalized seizure. It was the opinion of the neurologic surgeon that the amount of gas was insufficient, and ventriculography was performed the same day. This revealed symmetric and rather prominent dilatation of the lateral ventricles, with no displacement of these structures from the midline. There was a slight shift of the third ventricle to the right, together with upward displacement of its posteroinferior portion. The proximal portion of the aqueduct of Sylvius, visible for a distance of about 1.5 cm., was angulated anteriorly. The lowermost portion of the aqueduct and the fourth ventricle were not seen. No evidence of downward displacement of the cerebellar tonsils could be identified in the air-filled cisterna magna or upper cervical spinal canal.

These observations were regarded as indicative of a tumor high in the left cerebellum close to the midline.

The patient appeared to be quite stable after pneumoencephalography and his blood pressure was normal. Only a slight degree of undue restlessness was noted by the night nurse. However, about ten hours after ventriculography

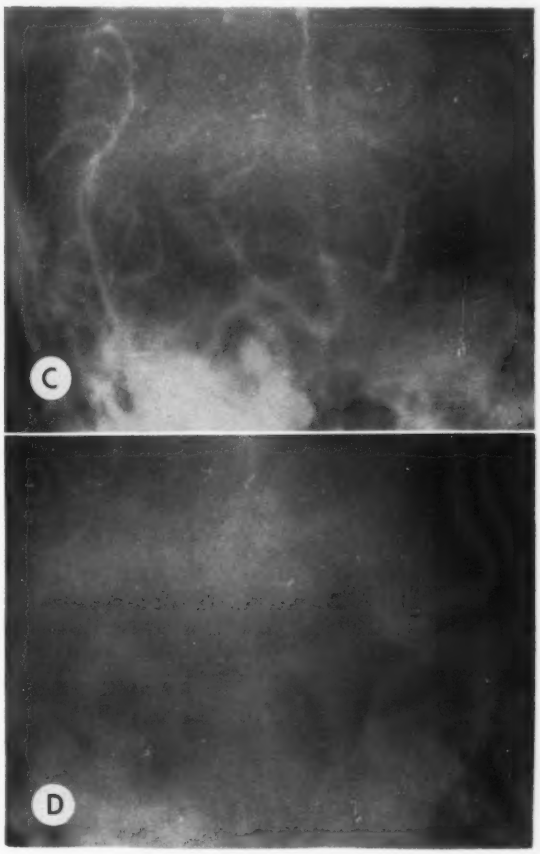

Fig. 1. (*C*) Anteroposterior right percutaneous cerebral angiogram. Both posterior cerebral arteries are well opacified. These are situated to either side of the anterior cerebral artery, which is in its normal midline position. The middle cerebral artery likewise is within normal limits. (*D*) Late venous phase of the same right carotid angiogphy. A tumor stain about 1.5 cm. in diameter can be seen above the petrous pyramid on the left side.

FIG. 1. (*E*) Left percutaneous cerebral angiogram shows no displacement of the anterior or middle cerebral arteries. The posterior cerebral artery on the left side is not filled. (*F*) Specimen of cerebellum with left cerebral hemisphere sectioned. A cystic tumor was cut through and the nodule of hemangioblastoma is identified as the dark structure in the middle of the reflected portion of the superior aspect of the left cerebellum.

the patient expired quite suddenly.

Postmortem examination was performed. The brain, after fixation, weighed 1,500 gm. The external surface was not remarkable except for burr hole defects about a centimeter in diameter over the occipital poles. The cerebral hemispheres were well developed and symmetric, with some swelling of the gyri and ironing out of the sulci bilaterally. At the base there was evidence of traumatic removal of the brain, most of the vessels forming the circle of Willis having been disrupted. The pons and medulla were distorted by swelling, and the basilar artery appeared to be deeply imbedded in the pontine substance. Over the superior pole of the left cerebellar hemisphere, which was somewhat larger than the right, an opaque, yellow-gray, firm nodule approximately 1 cm. in diameter was visible and palpable. Multiple frontal sections through the cerebral hemispheres showed no parenchymal lesions. The ventricles were moderately dilated with blunting of the lateral angles. The aqueduct appeared to be somewhat flattened. Sections through the cerebellum revealed an empty cystic space approximately 4 to 5 cm. in diameter which surrounded the nodule previously described in the left hemisphere (Fig. 1*F*). Its lining was poorly defined and had an opaque pale yellow discoloration. On section, the nodule itself was gray-brown in color and approximately 1.5 cm. in diameter. The medulla appeared voluminous, with obliteration of the surface markings suggesting some medullary swelling. There was no significant moulding of the cerebellar tonsils, nor was there any evidence of uncal herniation.

Histologic examination of the tumor disclosed a hemangioblastoma.

COMMENT

Inasmuch as the circle of Willis is the main distributing center for the blood supply to the brain, variations in its structure have an important influence on cerebral angiography,[3] as well as profound clinical significance in problems involving the development of collateral circulation. The relatively constant filling of the anterior cerebral vessels accounts for the frequency of roentgenologic identification of anatomic variations in these structures. However, the posterior communicating and posterior cerebral arteries are not visualized as often, and therefore the demonstration of their various anomalies is less frequent. Saltzmann[4] noted that the incidence of filling of the posterior cerebral arteries is somewhat greater when rapid serial angiography is done, preferably with injection into the internal carotid artery. In his experience the posterior cerebral arteries were seen in about 41 per cent of patients with injection into the internal carotid artery, as compared with about 25 per cent with common

carotid injections. The duration of visability of these vessels was variable, often being limited to the time when the contrast material was present in the syphon. The influence of the relative diameters of the posterior cerebral and posterior communicating arteries in maintaining such opacification was considered significant.

Recently, Alpers, Berry and Paddison[2] reviewed 350 normal brains and found that only 183 had the usually described symmetric polygonal pattern. Embryonic origin of the posterior cerebral artery from the internal carotid artery was encountered in 14.6 per cent of the circles. The most frequent anomaly was a filiform structure of one of the component vessels of the circle, involving most often one or both posterior communicating arteries, as occurred in 27.4 per cent of the circles. Multiple anomalies were found in 13.4 per cent of this series.

The roentgenologic diagnostic significance of variations in the posterior portion of the circle of Willis is emphasized by the present patient, in whom blood from the right internal carotid artery reached a tumor in the left cerebellar hemisphere by way of an unusually large right posterior cerebral artery which originated from the carotid syphon. This permitted filling of both posterior cerebral and superior cerebellar arteries. The opacified nodule in the hemangioblastoma was best seen in the arteriovenous and venous phases. A contralateral left carotid angiogram failed to demonstrate the left posterior cerebral artery.

CONCLUSION

A patient is reported in whom a left superior cerebellar hemangioblastoma was visualized during right percutaneous carotid angiography. This occurred because of an anomaly in the circle of Willis in which a large artery arose from the carotid syphon and permitted access to both posterior cerebral and superior cerebellar arteries.

The Long Island Jewish Hospital
270–05 76th Avenue
New Hyde Park, Long Island, New York

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TECHNIQUE OF INTRAVENOUS CAROTID AND VERTEBRAL ARTERIOGRAPHY*

By ISRAEL STEINBERG, M.D., *and* JOHN A. EVANS, M.D.
NEW YORK, NEW YORK

THE origins of the brachiocephalic arteries in the aortic arch have been visualized ever since intravenous angiocardiography was first described.[7,15] The recent modification of the Robb-Steinberg method, by which simultaneous and bilateral injections of concentrated organic iodides are made, has increased the bolus effect of the contrast agents and enhanced opacification of the *entire* aorta and its branches (brachiocephalic arteries, abdominal aortic and peripheral arterial tree).[21] By utilizing the same principles applied in these studies and by properly positioning the patient, visualization of the carotid-vertebral arterial circulations from their origins in the aortic arch to where they pierce the skull has been accomplished after intravenous injections.

The need for carotid and vertebral arteriography for the diagnosis and treatment of cerebral circulatory insufficiency has become quite evident judging from the reports of DeBakey and his co-workers[2–6] and others.[1,11,14] Indeed, several new methods for subclavian and carotid arteriography by direct arterial puncture or retrograde catheterization have been recently reported.[8,9,13] It would appear that an intravenous method of carotid-vertebral arteriography, particularly one that can be performed in the average, albeit well-equipped radiology department, might offer many advantages over the direct or retrograde multiple arterial puncture methods which are now required for the visualization of both vertebral and carotid arteries. For this reason, a technique of intravenous carotid and vertebral arteriography is herein described. It offers a simplified method for visualization of these vessels and, thereby, enhances diagnosis and treatment of cerebral arterial insufficiency.

TECHNIQUE

With the patient supine, special 12 gauge Robb-Steinberg needle stopcock units (made by Becton, Dickinson Company, Rutherford, New Jersey) are inserted either percutaneously or by cutdown into large veins in the arms (Fig. 1).[7,15,21] Through a cannula introduced in the arm, the modified circulation time is determined by injecting 3 cc. of 20 per cent sodium dehydrocholate (decholin) mixed with 15 cc. normal saline in the 50 cc. Robb-Steinberg 12 gauge syringe. In the very ill, unconscious or uncooperative patient, an objective, preliminary, modified circulation time can be determined by using 1 cc. of a 20 per cent aqueous solution of sodium succinate mixed with 15 cc. normal saline. An upward movement of the cricoid cartilage is the endpoint.[10]

If automatic serial roentgenographic apparatus is not available, a single roentgenogram of the carotid-vertebral arteries can be obtained by making a one or two second roentgen exposure at the time of the predetermined decholin circulation. Figure 2 shows the position of the recumbent patient. The neck is outstretched and the collimated tube is centered over the neck. Rapid simultaneous bilateral injections are made during inspiration and the breath is held during the period of the exposure of the roentgenogram. The patient must be cautioned not to breathe in too deeply or to "bear down" during inspiration when the arms are being injected with contrast material. This will avoid the Valsalva maneuver, which prevents blood flow into the

* From the Departments of Radiology and Medicine, The New York Hospital—Cornell Medical Center, New York, New York.
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Fig. 1. Photograph showing the frontal position for intravenous carotid-vertebral arteriography with serial roentgenography. The patient is supine with the head and neck on the roll-film magazine. Arrows point to the special cannulas in the antecubital veins which were inserted percutaneously and secured with adhesive tape.

superior vena cava. Another way to circumvent the Valsalva experiment is to have the patient breathe normally immediately after the injection is completed and then to hold his breath just prior to the time the roentgen exposures are made. If a serial roentgenographic apparatus such as F-X-R roll film magazine (Fig. 1)[16] is available, several roentgenograms at intervals of one to three per second may be made. In such instances and in order to make certain that roentgenograms with optimum opacification of the great arteries are secured, the exposures may begin three seconds before and end three seconds after the predetermined decholin circulation time. Multiple roentgenograms, varying from one to three per second, may be taken during the six second interval. In cooperative patients the erect sitting position with the patient's head against the cassette (Fig. 3, *A* and *B*) or against the rapid serial roentgenographic apparatus (Fig. 4) is advised. Here, too, roentgenograms made serially beginning three seconds before and continuing for three seconds after the predicted circulation time will prove satisfactory.

The intravenous method of carotid and vertebral arteriography is based upon the principles which have been developed for angiocardiography.[8,15,17,20,21] Speed of injection of the contrast material is essential and this is accomplished by simultaneously injecting the large veins of both arms. This eliminates the factor of dilution of the contrast medium by blood from the opposite innominate vein, which results when only one injection is made, and, of course, increases the bolus effect of the contrast agent into the circulation. Speed of injection is also facilitated by elevating the arms and having the patient perform respiratory maneuvers.

The percutaneous insertion of the 12 gauge Robb-Steinberg needle stopcock unit has been described previously.[8,15] In the

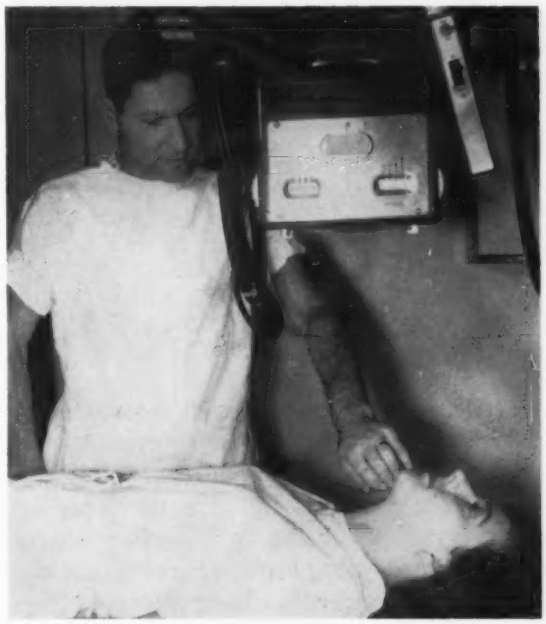

Fig. 2. Photograph showing the details of the frontal position for intravenous carotid-vertebral arteriography. The patient is supine with the neck extended and the collimated tube centered equidistant between the chin and clavicles.

FIG. 3. (*A*) Photograph showing the erect sitting position for frontal (anteroposterior) view of the brachiocephalic arteries. The patient's head and neck are against the stereo cassette (Bucky grid) changer. Note the elevation of the arms of the patient, the raised position of the injectors, and the alignment of the syringe and needle stopcock with the direction of the arm veins. (*B*) Close-up view of the frontal position for single film intravenous carotid-vertebral arteriography.

absence of a large vein, it may be necessary to perform a cut-down for insertion of the needle. The position of the needle stopcock is then secured by adhesive tape. To make certain that the cannula is properly seated in the vein, an injection of normal saline to safeguard against extravasation is advisable. The patient is then briefed about the technique of the examination and is instructed about breathing during the examination.

The determination of the preliminary circulation time with the patient supine will serve as a good rehearsal of the patient's participation in the test. Sodium dehydrocholate (decholin), 3 cc., is mixed with 15 cc. normal saline in a 50 cc. syringe and attached to one of the cannulas. The arm is then elevated, making certain that it is relaxed at the shoulder. (This avoids physiologic obstruction of the subclavian vein underneath the first rib.) The stopcock is then opened and the patient is instructed to "breathe out" gently. Then he is asked to "breathe in," making certain that only a moderate breath is taken, for it is important to avoid the Valsalva maneuver which tends to delay circulation into the heart. Injection of the decholin-saline mixture is made simultaneously with the direction to "breathe in." This also is the signal for the assistant to start the stopwatch. Once the injection is completed, the patient, having been told to anticipate a bitter taste, is urged to go through the motion of tasting by smacking his lips, tongue and mouth. This automatically releases the tendency to perform the Valsalva maneuver. The onset of the bitter taste is then recorded by stop-watch. The modified circulation time from arm to tongue is used as a guide for the starting time of the roentgen exposure for visualizing the carotid-vertebral arterial system. If the accuracy of this determination is uncertain, a repeat circulation time study is done.

The patient is told to anticipate an intense wave of heat soon after injection of the contrast medium and is assured that it will quickly pass. All is then ready for the arteriographic study. The special Robb-Steinberg syringes are loaded with concentrated organic iodide contrast material, the amount depending on the weight of the patient. A dose of 1 ml. per kg. of body weight divided equally for injection into each arm is advised. Up to 50 ml. in each arm may be necessary for obese patients weighing over 200 pounds. The syringes are then attached to the cannulas and the stopcock is opened. Two physicians standing on a platform, one on each side of the

FIG. 4. Photograph showing the position of the patient for frontal (anteroposterior) serial intravenous carotid-vertebral arteriography. Note the band over the thorax which secures the patient to the automatic roll-film magazine (arrow).

patient (Fig. 3*A*; and 4), begin the simultaneous injection into the elevated arms. At the signal, "breathe in," the technician starts the stop-watch. The injections are made rapidly and completed in one and one-half to two seconds. Because of the viscidity of some of the concentrated contrast agents, this may be difficult unless the mixture is warm. The patient is then told to "breathe naturally." Two or three seconds prior to the selected exposure time, the patient is asked to "stop breathing." Carotid-vertebral arteriograms are then taken while the patient holds his breath. If, after inspection, these prove satisfactory, the cannulas may be removed and a tight temporary bandage applied. There should be no hesitancy in repeating the injection after a short interval if the patient has tolerated the procedure well.

RESULTS

Forty-two patients have had carotid-vertebral arteriography with the intravenous technique. At the beginning, multiple serial roentgenograms were made using the roll-film cassette[16] with the patient in a supine position (Fig. 1) and proved satisfactory. Later, a single roentgenogram, exposed for a duration of one to two seconds, was tried. This required a Bucky-Potter diaphragm and several layers of aluminum filter to overcome the discrepancies between the thickness of the neck and thorax. Figures 5 and 6 showing buckling of the innominate and left common carotid arter-

FIG. 5. Single film intravenous frontal carotid-vertebral arteriography in a sixty-two year old woman in a supine position showing buckling of the innominate artery (arrow) due to hypertension and arteriosclerosis. The upper thorax measured 15 cm., the weight was 75 kg., and the decholin circulation time was nine seconds. A Bucky-Potter diaphragm was used with 50 ma. and an exposure time of two seconds with 58 kv. peak. The film was exposed for a duration of two seconds, beginning at eight seconds and ending at ten seconds after the beginning of the bilateral simultaneous injection of 37.5 ml. concentrated contrast medium into each arm. The distance of the tube to the table top was 40 inches.

FIG. 6. Single film, frontal intravenous carotid-vertebral arteriography in a sixty-six year old woman showing buckling of the innominate and left common carotid artery due to hypertension and arteriosclerosis. The patient weighed 77 kg., the thickness of the upper thorax was 14 cm., and the decholin circulation time was twelve seconds. The roentgen exposure was started at eleven seconds and ended at thirteen seconds after the beginning of injection of 38 ml. concentrated contrast agent, into each arm. The Bucky-Potter grid was used, the milliamperage was 50 and the exposure time two seconds at 56 kv. peak. The distance of the tube to the table top was 40 inches.

ies[12] are examples of this technique. In cooperative patients, highly satisfactory roentgenograms were also obtained when they were injected while seated in the erect position with the neck and upper thorax against a cassette containing film (Fig. *3A* and 4). Frontal studies of the carotid vertebral arterial system were equally good when the patient faced the film (anteroposterior position) or when the head and neck were against the cassette (posteroanterior position). Because of overlapping shadows of the brachiocephalic arteries, especially the origins of the vertebral arteries, oblique studies were found to be necessary. These also permitted better visualization of the carotid arteries beyond their bifurcation into the external and internal branches (Fig. 7). The most satisfactory arteriogram resulted when the patient was placed in the seated, right posterior oblique position with the head, neck and upper thorax against the serial roentgenographic device.

DISCUSSION

In order to perform carotid and vertebral arteriography via the intravenous route, meticulous attention to the details of the Robb-Steinberg method of angiocardiography is advised.[7,15,17,20,21] The special 12 gauge cannulas and syringes are essential for speed of injection of the concentrated organic iodides. The bilateral, simultaneous injections allow the contrast agent to enter and emerge from the cardiovascular system as a bolus, thereby resulting in excellent opacification of the aorta and its branches.[21]

The commercially available concentrated contrast agents (ditriokon, hypaque 90 per cent and cardiografin) are well tolerated intravenously in the dosage of 1 ml. per kg. of body weight even when divided equally for injection into each arm. The usual reaction to the simultaneous double injection is mild and transient and much like that of angiocardiography with a single injection, except that there is a more intense flush and a greater wave of heat from head to toes. In over 350 consecutive patients receiving bilateral simultaneous intravenous injection, most of them for abdominal aortography and peripheral arteriography, there were 1 fatality and 2 severe reactions. One patient developed circumoral pallor and orbital edema at the conclusion of a single bilateral injection; antihistamine therapy quickly alleviated the symptoms. The other patient developed mild hypotension, fever and leukocytosis for a period of six hours following three double injections. The fatality occurred in a seventy-four year old man with moderately severe peripheral, cardiovascular and cerebral arteriosclerosis. There was no immediate reaction to two bilateral injections of

contrast material, but six hours later there was sudden onset of pulmonary edema. The electrocardiogram did not show arrhythmia or myocardial infarction. Death occurred forty-one hours after the intravenous study; pulmonary edema and advanced arteriosclerotic cerebral, cardiac, aortic and and peripheral vascular disease were demonstrated at autopsy. The immediate cause of death could not be ascertained. Two other fatalities have occurred in our series of 4,700 patients studied angiocardiographically (after two single injections). The first, a fifty-six year old woman had postirradiation pericardial effusion and died five hours after injection of contrast material.[18] The other, a six year old child with primary pulmonary hypertension, died immediately after injection of the contrast medium.[19] Since the patients undergoing angiocardiography usually have serious circulatory handicaps, the rare fatality due to the procedure should not contraindicate the study. Furthermore, because it offers a prospect of clarifying a diagnosis and deciding whether a case is operable, the risk involved in angiocardiography is certainly less than the risks of not treating or incorrectly treating the disease.

Comparison studies of the circulation time with decholin and sodium succinate indicate that the modified objective circulation time with the latter substance is from two to six seconds longer than the decholin circulation time. Accordingly, when the uncooperative or unconscious patient is studied, contrast roentgenography of the carotid and vertebral arteries can be performed by making roentgen exposures at least six seconds before the predetermined sodium succinate circulation time and ending the exposures at the sodium succinate circulation time.

Studies of the aortic arch branches when the patient is in the supine position may show the subclavian veins (Fig. 6) because in this position there is a tendency for the contrast material to be retained at the site where the veins enter the thorax. This may interfere with visualization of the third portion of the subclavian arteries and, rarely, may tend to obscure the origins of the vertebral arteries. Accordingly, whenever feasible, the erect sitting position (Fig. 3, *A* and *B*; and 4) is advised.

The physicians making the injection receive very little exposure if the roentgen-ray beam is suitably collimated and conventional protective garments are worn.[21] As a further precaution, once the injection is completed, the syringes may be detached from the stopcocks and the arms of the patient placed at the side on the roentgen

Fig. 7. Serial intravenous left anterior oblique study of the normal carotid-vertebral arterial system of a seventy year old woman who complained of headache, dizziness, facial weakness and partial blindness of the right eye. The patient was seated in the erect right posterior oblique position with her head and neck against the roll-film magazine. The upper thorax measured 14 cm. The patient weighed 61 kg. and the decholin circulation time was ten seconds. Serial (12 by 12 inch) roentgenograms were made at intervals of 2 per second, beginning at eight seconds and ending at twelve seconds. The milliamperage was 200 and the exposure time 0.1 second at 78 kv. peak. The distance of the tube to the table top was 40 inches.

table if the patient is recumbent or rested against a support if he is in the erect sitting position. The operators can then move to a shielded area. Sufficient time for this is afforded because the exposure of the roentgenogram is usually made six seconds or more after the beginning of injection and the injection is usually concluded at the end of two seconds.[21] The personnel for performance of vertebral and carotid arteriography via the intravenous route consists of 2 physicians who make the injections and a technician. This is much less formidable than direct arterial puncture or retrograde carotid and cerebral arteriography where sterile precautions must be maintained, necessitating a trained attendant. Since general anesthesia is not required for the intravenous arteriographic study, an anesthesiologist is not needed.

Determination of the preliminary modified circulation time with decholin prior to the injection of the contrast material is advised for every patient. This also determines whether there is obstruction (physiologic or pathologic) to blood flow into or within the heart. Delay of passage of the contrast material occurs in cases of pulmonary disease associated with cor pulmonale, some types of congenital heart disease (Ebstein's anomaly, aortic stenosis), congestive heart failure and acquired valvular disease such as mitral and aortic stenosis or regurgitation. Fortunately, patients requiring carotid and vertebral arteriography are usually without congenital heart disease, congestive heart failure, or rheumatic valvular heart disease.

Because the carotid-vertebral arterial opacification time is short, only a few serial roentgenograms are needed. The commercially available automatic serial film devices such as the Schönander, Sanchez-Perez, and home-made manual changers can be used for arteriography of the vessels of the aortic arch (Fig. 1 and 4). Even a single roentgenogram made with the Bucky grid at the predetermined decholin circulation time has proved satisfactory (Fig. 6 and 7). As in angiocardiography and abdominal aortography, a second bilateral injection may be made without harm to the patient soon after the first study is evaluated. Ideally, biplane studies should enhance carotid and vertebral arteriography by providing three dimensional views, thus obviating the need for a second series of injections for oblique or lateral views of the vessels.

SUMMARY AND CONCLUSIONS

Utilizing the modified Robb-Steinberg technique of rapid, bilateral and simultaneous intravenous injection of concentrated organic iodides through special needle stopcock units and syringes, the visualization of the carotid-vertebral arterial system from its origin in the aortic arch to above the bifurcation into the external and internal carotid arteries can be achieved. Sufficient radiopacity of the neck vessels readily permits identification of occlusions, stenoses, aneurysms or arteriosclerotic plaques.

For intravenous carotid and vertebral arteriography a single roentgenogram exposed for a period varying from one to two seconds at the predetermined decholin circulation time is sufficient and, therefore, the procedure can be performed in the average well-equipped radiology department. Rapid serial roentgenography by means of automatic or manual devices increases the chances of securing excellent roentgenograms. In seriously ill or unconscious patients the supine position is recommended. Superior studies can be obtained in cooperative patients who are well enough to be seated in the erect position. This permits either frontal or oblique views; the latter eliminates the confusing overlapping shadows of vessels.

The intravenous method of carotid-vertebral arteriography obviates the need of multiple arterial punctures when both carotid and vertebral arteries need to be visualized. Since the entire course of the brachiocephalic arteries, especially at their origins in the aortic arch, is demonstrated, examination of the area proximal to the site of arterial puncture is possible. While subclavian or femoral retrograde catheterization and injection of the contrast material

at the aortic arch in the vicinity of the brachiocephalic arteries allows better opacification and visualization of the arteries of both sides of the neck, the morbidity of this procedure, especially in the arteriosclerotic group, is probably greater than when intravenous techniques are used.

Israel Steinberg, M.D.
The New York Hospital—
Cornell Medical Center
525 East 68th Street
New York 21, New York

ADDENDUM

Since this paper was submitted for publication two reports, describing some modification of the intravenous method of carotid-vertebral arteriography described above, have been published. (Zerbi-Ortez, A., and Weldon, W. V. Aortography by catheterization of the right atrium: a safe and reliable method. *New England J. Med.*, 1961, *264*, 19–23; and Schramel, R., Creech, O., Jr., Llewellyn, R. L., and Corales, R. Visualization of the extracranial cerebral circulation by cardio-angiography. *J.A.M.A.*, 1961, *175*, 304–305.)

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A NEW DEVICE FOR LAMINAGRAPHY

By HYMER L. FRIEDELL, M.D.
CLEVELAND, OHIO

ORDINARILY, laminagrams are produced by moving the tube and film in opposite directions. The motion of the tube and film is regulated by a rigid mechanical linkage connecting the two, which moves about a fulcrum which fixes the level of the body section.

It can be shown by relatively simple analysis that a laminagraphic device may be developed with independent motion of the roentgen-ray tube and the film. In such a device, it is necessary to make certain that the velocity of the tube motion and the velocity of the film motion are maintained in some constant ratio ($V_t/V_f = K$) and that these velocities are in the appropriate opposing directions.

During the past six months we have constructed a laminagraphic device in which there is no mechanical linkage between the tube and the film. The tube carriage is moved independently by a motor at a constant velocity. The film, in turn, is moved independently by another motor at any specified constant velocity which may be varied at will.

The level of the body sectioning is determined by the ratio of V_t/V_f. If V_t and V_f are equal, the level of sectioning will lie half way between the tube and film. All levels above and below, of course, are blurred out. If the ratio increases (V_t becomes greater than V_f), the plane of sectioning moves closer to the film. If the ratio decreases (V_t becomes smaller than V_f), the plane of sectioning moves closer to the tube.

Laminagrams are being produced by this device and appear to be of excellent quality.

A fuller, more complete report will be given shortly.

University Hospitals
2065 Adelbert Road
Cleveland 6, Ohio

THE AMERICAN JOURNAL OF ROENTGENOLOGY, RADIUM THERAPY AND NUCLEAR MEDICINE

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Forty-third Annual Meeting: Broadmoor Hotel, Colorado Springs, Colo., May 10–14, 1961.

* *Ex officio.*

EDITORIAL

PSEUDO-PHEOCHROMOCYTOMA

THE recent description of a case in which a fibrosarcoma uniquely arose from the pulmonary artery and extended into its main branches but clinically simulated a pheochromocytoma is one of the most interesting instances of intravascular tumor to have been described.[1]

The simulation of pheochromocytoma by such conditions as the carcinoid syndrome, carotid sinus syndrome and paroxysmal hypertension of other origin presents a difficult problem in differential diagnosis. Its occurrence with hysterical laryngeal spasm was observed by Tyrer, Emmerson and Murphy.[2] One of the 2 patients reported by them clinically exhibited the picture of a pheochromocytoma characterized by paroxysms of headaches, chest pain, palpitations, and arterial hypertension. False positive provocative histamine and phentolamine tests were also noted. Anxiety states and emotional stress provide additional perplexing problems in differential diagnosis, since paroxysmal hypertension of pheochromocytoma may be thus triggered or such conditions alone may mimic the presence of this tumor. Anxiety or hysteria occurring with hyperventilation has been seen to simulate pheochromocytoma as well. Vascular headaches, cerebral vascular accidents, chronic nervous fatigue, menopausal tension, angioneurotic edema, epilepsy and the diencephalic seizures of Penfield are some other conditions which may be confused with pheochromocytoma.[3] Within recent years the ability to recognize these lesions by pharmacologic investigative procedures has made the diagnosis somewhat more certain and the classification of hypertension of unexplained origin has been assisted.

Similarly, the recognition of functioning or metastatic carcinoid tumors has been greatly facilitated by the demonstration of hyperserotoninemia (the elevation of 5-hydroxytryptamine in the serum) or more practically of 5-hydroxyindoleacetic acid in the urine. Toomey and Felson[4] call attention to the relationship of abdominal carcinoid and bronchial adenoma of the carcinoid type as being related entities. The second of these, although different in location than the fibrosarcoma of the pulmonary artery reported by Wolf, Dickenman and Langston,[1] is representative of still another intrathoracic lesion which may be confused with pheochromocytoma.

The ability to demonstrate pheochromocytoma by roentgenologic methods centers primarily on excretory urography to show displacement of the kidneys, although only approximately 50 per cent of these tumors are of sufficient size to cause displacement. Where suspected, retroperitoneal or perirenal air insufflation has been employed to delineate such tumors. In addition to the objection of a procedure somewhat difficult to perform satisfactorily and the remote hazard of air embolism, the low degree of accuracy in revealing

[1] WOLF, P. L., DICKENMAN, R. C., and LANGSTON, J. D. Fibrosarcoma of the pulmonary artery, masquerading as a pheochromocytoma. *Am. J. Clin. Path.*, 1960, *34*, 146–154.

[2] TYRER, J. H., EMMERSON, B. T., and MURPHY, K. J. Hysterical laryngeal spasm and the production of paroxysmal hypertension. *Quarterly J. Med.*, 1959, *28*, 315–327.

[3] HARDIE, G. H., and SUECHTING, R. L. Pheochromocytoma. *J.A.M.A.*, 1960, *174*, 1533–1537.

[4] TOOMEY, F. B., and FELSON, B. Osteoblastic bone metastasis in gastrointestinal and bronchial carcinoids. AM. J. ROENTGENOL., RAD. THERAPY & NUCLEAR MED., 1960, *83*, 709–715.

known tumors must be taken into consideration. Therefore, from the roentgenologic standpoint, the demonstration of pheochromocytoma is uncertain and often impossible, requiring surgical exploration. Allen[5] successfully detected the location of a pheochromocytoma and proved it to be unilateral by translumbar aortography, reasoning that it would have a good vascular supply. He states that perirenal air insufflation and laminagraphy with or without excretory urography are the methods of choice in diagnosis. Noting a report of 2 deaths from this procedure, possible hazard is minimized by a nor-adrenaline and phentolamine drip to stabilize the blood pressure. Elfvin[6] states that 22 histologically verified cases of suprarenal tumors demonstrated by aortography had been published prior to March, 1959. A pheochromocytoma which he clearly recognized preoperatively revealed tumor vessels without arteriovenous fistulas and moderate diffuse contrast material accumulation in the tumor during the arterial phase.

The suggestion of a pheochromocytoma by clinical signs and symptoms which could not be excluded by a number of pharmacologic and roentgenologic investigations is the subject of Wolf, Dickenman, and Langston's interesting report.[1] In their case excretory urography and retroperitoneal air insufflation did not obviate an exploratory operation which in turn failed to demonstrate a suprarenal tumor. The symptomatology was misleading and, curiously, palpation of the abdomen was followed by an episode of hypertension. Further confusion resulted from positive Regitine tests, the presence of an atypical pressor-like substance in the urine and the occurrence of paroxysmal hypertension. This case represents a rare entity, but an awareness of the mechanism wherein an intra-arterial pulmonary tumor produced the clinical picture of pheochromocytoma may lead to its more frequent recognition. Roentgenographically, a prominent and enlarged right pulmonary artery was demonstrated and subsequently proved to be infiltrated by the tumor.

The possible manner of production of paroxysmal hypertension in this case is postulated by the authors to result from (1) a pressor substance elaborated by the tumor, (2) the secretion of an insulin-like substance with hypoglycemia resulting in excessive secretion of adrenal medullary hormone, and (3) intrinsic reflexes of the carotid sinus and aortic sinus due to pressure changes within the vascular system.

There have been numerous reports in the literature of conditions which produce paroxysmal hypertension and to this should be added fibrosarcoma of the pulmonary artery. It should again be emphasized that, despite its rarity, the awareness of an intravascular tumor occurring in the pulmonary artery and simulating pheochromocytoma may enable the radiologist to direct the clinician's attention to this entity. The employment of venous angiocardiography, selective angiocardiography or selective pulmonary arteriography may then lead to earlier recognition.

Kenneth L. Krabbenhoft, M.D.

Harper Hospital
Detroit 1, Michigan

[5] Allen, W. M. C. Pheochromocytoma demonstrated by trans-lumbar aortography. *Brit. J. Rad.*, 1960, *33*, 649–650.

[6] Elfvin, P. Roentgen findings in a case of phaeochromocytoma. *Acta radiol.*, 1959, *52*, 461–464.

NEWS ITEMS

DR. BERNARD PIERRE WIDMANN HONORED

A Testimonial Dinner was given by the Philadelphia Roentgen Ray Society in honor of Bernard Pierre Widmann, M.D., at the Union League of Philadelphia, on Thursday, March 2, 1961.

DR. TRUMP AWARDED 1961 AIEE LAMME MEDAL

The American Institute of Electrical Engineers announced the award of the 1961 Lamme Gold Medal to Dr. John G. Trump of Massachusetts Institute of Technology, Cambridge, Mass. The Medal will be presented to Dr. Trump at the opening of the five-day Summer General Meeting of AIEE at Cornell University, June 19–23, 1961.

COURSE IN OPERATIVE RADIUM THERAPY

A course in Operative Radium Therapy is to be offered at the Queens Hospital Center by the Radiation Medicine Department. The course will be held on Wednesday mornings (9 A.M. to 12 NOON) from October 4, 1961 to November 22, 1961.

The program will include the use of interstitial radiation in the oral cavity; radical insertion of radium in the neck; various applicators in carcinoma of the cervix; the Heyman applicators in carcinoma of the endometrium; radium needles in the parametria; and radon, iridium-thread, and cobalt interstitial therapy.

The tuition fee is $100. For further information apply to Dr. Philip J. Kahan, Supervising Medical Superintendent, Queens Hospital Center, 82-68 164th Street, Jamaica 32, New York.

FELLOWSHIPS IN HEALTH PHYSICS

Next fall, as the 1961–62 academic year opens, 61 young graduate students will embark on studies in the field of health physics under a unique program sponsored by the U. S. Atomic Energy Commission.

Administered for the Commission by the Oak Ridge Institute of Nuclear Studies, the AEC Special Fellowships in Health Physics have been awarded to 61 outstanding students to enable them to become specialists in a branch of science that has grown out of the atomic age.

The fellowship awardees will spend nine months of regular graduate work at one of eight universities participating in the program, followed by three months of additional study and field training at a cooperating installation of the AEC. The knowledge and experience they thus gain will train them in the methods and techniques of identification and evaluation of, and protection from, effects of ionizing radiation—a scientific field essential to many U. S. industries that are now using radioisotopes and radiation in industrial processes.

The fellowship appointees will study at one of the following universities: Vanderbilt; the Universities of Washington, Rochester, California, Michigan, Kansas, Puerto Rico; or Harvard.

AEC SPECIAL FELLOWSHIPS IN NUCLEAR SCIENCE AND ENGINEERING

One hundred and eighty-four young science students from 32 states and the District of Columbia have been selected to receive special Atomic Energy Commission fellowships for graduate study during 1961–62.

The AEC Special Fellowships in Nuclear Science and Engineering to which they were appointed are designed to aid and encourage outstanding students who are studying for master's or doctor's degrees in nuclear fields. Administered for the Commission by the Oak Ridge Institute of Nuclear Studies, the fellowships are awarded for one year, and may be used for study at one of 54 designated universities in the United States.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

VASO-SEMINAL VESICULOGRAPHY IN HYPERTROPHY AND CARCINOMA OF THE PROSTATE WITH SPECIAL REFERENCE TO THE EJACULATORY DUCTS; A CLINICAL AND EXPERIMENTAL ROENTGENOLOGICAL STUDY. By Gunnar Willer Vestby. Cloth. Pp. 194, with 119 illustrations. Oslo University Press, 1960. Distribution office in the United States, 355 North St., Boston 9, Mass. Also published as Supplement 199 to *Acta Radiologica*.

In the literature dealing with roentgenology of the genitourinary tract, considerable detailed information is given on the kidneys, ureters, bladder and urethra. Very little space, however, is devoted to the roentgenology of the spermatic tract. The purpose of the author has been to study the roentgen findings of the ejaculatory duct and the contiguous part of the spermatic tract in cases of benign hypertrophy and carcinoma of the prostate, and to evaluate the diagnostic roentgen examination known as vasoseminal vesiculography.

The book is divided into two parts dealing with clinical and experimental roentgenology, respectively.

The first part is a presentation of vasoseminal vesiculography as it was performed on 230 patients with hypertrophy and carcinoma of the prostate. In this investigation the author has concentrated particularly on that portion of the spermatic tract which penetrates the prostate, namely, the ejaculatory duct. To ensure complete contrast-filling and visualization of the ejaculatory duct, roentgenograms were made during the injection of the contrast medium. All roentgenologic studies were performed in conjunction with vasectomy. A detailed description of the author's technique and equipment is given and the normal vasoseminal vesiculogram is described. Inflammatory lesions frequently cause pathologic changes in the prostate and the spermatic tract. Consequently, the roentgen changes in relation to the differential diagnosis of hypertrophy and carcinoma of the prostate are discussed.

The second part describes an experimental study of postmortem specimens. To obtain detailed information of the roentgen changes and their morphologic basis, the spermatic tract in fresh autopsy specimens was filled with contrast medium and roentgenograms were made prior to the histologic examination. Exact descriptions of the method employed and of the author's technique for preparing the specimens are given.

The following observations were made:

The roentgen changes in prostatic carcinoma are well defined and generally differ distinctly from those in benign hypertrophy. In prostatic carcinoma, the ejaculatory duct is narrowed and tube-like, and, in pronounced cases, may even be completely obliterated. Histologically, it is demonstrated that the constricting growth of the malignant tumor produces the narrowing of the duct. In early carcinoma, these changes are noted only in the ejaculatory duct. In advanced carcinoma there are also changes in the seminal vesicle and ampulla of the ductus deferens.

In benign hypertrophy, the roentgen findings are practically the opposite of those in prostatic carcinoma. The ejaculatory duct is dilated, if not normal, and the seminal vesicle is excessively dilated. In chronic seminal vesiculitis with shrinking and inflammatory infiltration, the findings on the vasoseminal vesiculogram may be confused with those of advanced prostatic carcinoma.

In the vast majority of cases of benign hypertrophy and prostatic carcinoma it is easy to establish a definite diagnosis, but evaluation of the vasoseminal vesiculograms demands considerable experience and may be difficult.

The author concludes that: (1) vasoseminal vesiculography, when properly performed, is a practical and valuable method in the diagnosis of benign hypertrophy and carcinoma of the prostate; and (2) in the presence of carcinoma, vasoseminal vesiculography gives useful information on the local extent of the lesion, a point of great importance in the consideration of radical prostatectomy.

The indications for vasoseminal vesiculography may briefly be summarized as follows: (1) all cases of benign hypertrophy and carcinoma of the prostate, in which the diagnosis is still uncertain after routine examination; (2) all

cases of prostatic carcinoma in which radical prostatectomy is contemplated, since it is desirable to know the extent of the lesion; and (3) all cases in which vasectomy is proposed. This is of special importance in surgical and urologic departments, where radical prostatectomy is the usual procedure for operable cases of prostatic carcinoma.

The book is enriched with reproductions of numerous roentgenograms of excellent quality, an anatomic drawing of the spermatic tract and a splendid presentation of the author's technique for vasoseminal vesiculography.

Prof. Athayde Pereira, M.D.
São Paulo, Brasil

Strahlenbiologie; Grundlagen und Ergebnisse. By Prof. Dr. Hedi Fritz-Niggli, Zürich. Cloth. Price, $15.50. Pp. 379, with 168 illustrations. Georg Thieme Verlag, Herdweg 63, Stuttgart, Germany, 1959. In the U.S.A. and Canada, Intercontinental Medical Book Corporation, New York 16, N. Y.

The interest in biologic effects resulting from ionizing radiations has increased tremendously since radioisotopes are being produced in great quantities and varieties and since supervoltage apparatus, accelerators and nuclear reactors of even greater energies are being constructed. One of the underlying reasons for this development is the concern about the health and safety of the public in general and of workers coming in contact with ionizing radiations in particular.

Investigations on radiation biology are being carried out in many laboratories all over the world and the literature on the subject has taken on gigantic proportions. The author of this book very successfully arranges the vast amount of published material in an orderly systematic manner, adding a large part of her own work in the field.

A rather extensive description of the physical and chemical foundations of radiation biology leads up to a consideration of radiation genetics —the effects upon cells and cell division, the embryo, fetus and regeneration.

The second half of the book is devoted to cancer-producing effects of radiations, radiation pathology, radiation death and radiation sickness in mammals and humans. A description of biologic and chemical means of prophylaxis and therapy for radiation injuries and an attempt to explain some of these effects on a theoretic basis concludes the book. Questions of radiation genetics are described in greater detail, since the effects of ionizing radiation upon hereditary factors are considered to be especially important, both from a theoretic and a practical point of view. The discussion of the author's own work in the field is especially stimulating.

The book is excellently printed and has a large number of excellent illustrations, some of them in color. It fills a definite gap of long standing and should be found in every laboratory and institution where work is carried out on biologic effects of ionizing radiations.

Otto Glasser, Ph.D.

BOOKS RECEIVED

Cancer; Progress Volume 1960. Edited by Ronald W. Raven, O.B.E.(Mil.), T.D., F.R.C.S., Joint Lecturer in Surgery, Westminster Medical School, University of London; Surgeon, Westminster Hospital Teaching Group; Surgeon, The Royal Marsden Hospital, London; Surgeon, The French Hospital, London. Cloth. Pp. 258, with 45 illustrations. Price, $12.00. Butterworth, Inc., 7235 Wisconsin Ave., Washington 14, D. C., 1960.

Neuroradiology Workshop. Volume I: Scalp, Skull and Meninges, By Leo M. Davidoff, M.D., Active Consultant Neurosurgeon, Montefiore Hospital; Professor and Chairman, Department of Neurosurgery, Albert Einstein College of Medicine, Yeshiva University, New York; Harold G. Jacobson, M.D., Chief, Division of Diagnostic Radiology, Montefiore Hospital; Professor of Clinical Radiology, New York University School of Medicine, New York; and Harry M. Zimmerman, M.D., Chief, Division of Laboratories, Montefiore Hospital; Professor of Pathology, College of Physicians and Surgeons, Columbia University, New York. Cloth. Pp. 256, with many illustrations. Price, $16.50. Grune & Stratton, Inc., 381 Fourth Ave., New York 16, N. Y., 1961.

Anatomy and Physiology for Radiographers. By J. E. Blewett, M.D., D.M.R., F.F.R., Director of Diagnostic Radiology Department, King's College Hospital, London, and the Belgrave Hospital for Children; and A. M. Rackow, B.Sc., M.B., D.M.R.E., Assistant Director of Diagnostic Radiology Department, King's College Hospital, London, and the Belgrave Hospital for Children. Cloth. Pp. 364, with 133 illustrations and 22 plates. Price, $7.50. Butterworth, Inc., 7235 Wisconsin Ave., Washington 14, D. C., 1960.

Surgery of the Esophagus. By Raymond W. Postlethwait, M.D., Professor of Surgery, Duke University Medical Center; Chief of Surgery, Veterans Administration Hospital, Durham, North Carolina; and Will Camp Sealy, M.D., Professor of Thoracic Surgery; Chief, Division of Thoracic Surgery, Department of Surgery, Duke University

Medical Center, Durham, North Carolina. Cloth. Pp. 482, with 201 illustrations. Price, $30.00. Charles C Thomas, Publisher, 301–327 East Lawrence Ave., Springfield, Ill., 1961.

The Physics of Radiology. Second edition. By Harold Elford Johns, M.A., Ph.D., F.R.S.C., LL.D., Professor of Physics and Professor of Medical Biophysics, University of Toronto; Head, Physics Division, Ontario Cancer Institute, Toronto, Canada. Cloth. Pp. 767, with many illustrations and tables. Price, $23.00. Charles C Thomas, Publisher, 301–327 East Lawrence Ave., Springfield, Ill., 1961.

Recent Advances in Human Genetics. Edited by L. S. Penrose, M.A., M.D., F.R.S., Galton Professor of Eugenics, University College, London. Cloth. Pp. 194, with 13 illustrations and 32 tables. Price, $8.00. Little, Brown & Company, 34 Beacon St., Boston 6, Mass., 1961.

Pediatric X-Ray Diagnosis; A Textbook for Students and Practitioners of Pediatrics, Surgery & Radiology. Fourth edition. By John Caffey, A.B., M.D., Director of Medical Education, Children's Hospital of Denver; Consultant Pediatrician, National Jewish Hospital at Denver, Colorado; Professor Emeritus of Radiology, College of Physicians and Surgeons, Columbia University; Consultant Radiologist, Columbia-Presbyterian Medical Center, New York City. Cloth. Pp. 1,236, with 1,536 illustrations. Year Book Publishers, Inc., 200 East Illinois St., Chicago 11, Ill., 1961.

Bibliotheca Radiologica, Supplementa ad "Radiologia Clinica," Fasc. 2. Gastroenterologische Röntgenprobleme, Gallenblase, Gallenwege, Colon; Problèmes Gastro-entérologiques et Radiologiques, Vésicule, Voies Biliaires, Colon. By E. Hafter, Zürich; M. Ramseyer, Lausanne; and J. Wellauer, Zürich. Paper. Pp. 104, with many illustrations. Price, $5.30. S. Karger, Basel, 1961. Available in the U.S.A. through Albert J. Phiebig, American Representative of Foreign Publishers, P.O. Box 352, White Plains, N. Y.

Dosimetrie der Strahlungen radioaktiver Stoffe. By Dr. phil. Walter Minder, Professor für medizinische Strahlenphysik an der Universität und Leiter des Radium-Institutes in Bern. Cloth. Pp. 300, with 137 illustrations. Price, $15.25. Springer-Verlag, Mölkerbastei 5, Wien 1, Austria, 1961.

Die Myelographie mit Positiven Kontrastmitteln. By Priv.-Doz. Dr. med. J. Wellauer, Zürich. Cloth. Pp. 176, with many illustrations. Price, $12.85. Georg Thieme Verlag, Herdweg 63, Stuttgart, Germany, 1961.

Gynäkologische Urologie. By Dr. med. et rer. nat. W. Langreder, apl. Prof. an der Joh. Gutenberg-Universität, Mainz, Chefarzt der Städt. Frauenklinik Rheydt (RHLD.). Cloth. Pp. 306, with 135 illustrations and 9 tables. Price, $14.05. Georg Thieme Verlag, Herdweg 63, Stuttgart, Germany, 1961.

Effects of Inhaled Radioactive Particles; Report of the Subcommittee on Inhalation Hazards, Committee on Pathologic Effects of Atomic Radiation. Publication 848. Paper. Pp. 78, with many illustrations and tables. National Academy of Sciences—National Research Council, Washington, D. C., 1961.

Report of the Subcommittee on Long-Term Effects of Ionizing Radiations from External Sources of the Committee on Pathologic Effects of Atomic Radiation. Publication 849. Paper. Pp. 82. National Academy of Sciences—National Research Council, Washington, D. C., 1961.

Effects of Ionizing Radiation on the Human Hemapoietic System; Report of the Subcommittee on Hematologic Effects, Committee on Pathologic Effects of Atomic Radiation. Publication 875. Paper. Pp. 14. National Academy of Sciences—National Research Council, Washington, D. C., 1961.

ABSTRACTS OF RADIOLOGICAL LITERATURE

Department Editor: T. Leucutia, M.D., Harper Hospital, Detroit 1, Michigan

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ROENTGEN DIAGNOSIS

Head

Updegrave, W. J. (Philadelphia, Pennsylvania.) Higher fidelity in intraoral roentgenography. *J. Am. Dent. A.*, Jan., 1951, *62*, 1–8.

Inaccurate portrayal of anatomic relationship of structures, superimposition of the parts, and over-all lack of intimate detail are inadequacies commonly seen in bisecting-angle roentgenograms. Such dimensional distortion can be minimized by a technique in which the film is positioned parallel to the object and then directing the rays at right angles to the film. Thereby, three-dimensional objects are projected with all parts in their correct relationship. In addition to the alignment, the film-target distance is increased to 16 inches to minimize enlargement.

To position and hold the film parallel to the long axes of the teeth and help project the beam perpendicular to the film, a simple device of plastic is designed.

Difficulties in positioning the film packet due to shallow palate and other problems are resolved by the author. An extension cone is recommended for proper distance. Several explanatory photographs and diagrams are included in the original article which aid in improving the interpretation of dental roentgenograms.—*David C. Alftine, M.D.*

Schechter, Mannie Menachem, and Jing, Bao-Shan. Improved visualization of the ventricular system with the technic of autotomography. *Radiology*, April, 1960, *74*, 593–600. (Address: M. M. Schechter, St. Vincent's Hospital of the City of New York, New York, N. Y.)

The use of autotomography in achieving improved visualization of the ventricular system in pneumography is described. Better definition of the fourth ventricle, aqueduct, and third ventricle is obtained due to the fact that the axis of rotation of the head passes through them and, therefore, the shadows cast by these structures move far less than those at a distance from the midline.

During encephalography, the patient is placed in a sitting position with the neck flexed. During the introduction of air, he is instructed to rotate the head slowly from side to side as if saying "no." Exposures are made during this rotation, which is approximately 10 degrees, *i.e.*, 5 degrees to each side of the midline. The brow up and brow down encephalograms are obtained with the patient lying down and the head rotated by an assistant.

The authors feel that this technique gives better visualization of the ventricular system in most instances and thus obviates the need for positive contrast ventriculography.—*John S. Alexander, M.D.*

Feiring, Emanuel H., Shapiro, Jerome H., and Feldman, Avner I. Frontal avascularity: an angiographic observation in frontal lobe tumors. *Radiology*, April, 1960, *74*, 601–604. (Address: J. H. Shapiro, Montefiore Hospital, New York 67, N. Y.)

This article is concerned with avascularity seen in the frontal regions during the postarterial phase of cerebral angiography in the presence of a frontal lobe tumor. The authors have noted that occasionally this phenomenon is demonstrated, especially when an automatic rapid film changer is used. In 41 cases of frontal lobe tumor, 27 showed absence or diminution of opacified blood vessels in the frontal region in the venous or "intermediate" phases. The exact explanation of this avascularity is not known, but it may be due to a pressure gradient rendering the small veins more liable to compression, or simply to bulk alone, since this is a "silent area."

It is realized that this phenomenon is of limited value for localization. However, when for anatomic reasons the anterior cerebral artery is not visualized on the side of the injection of contrast material, frontal avascularity in the postarterial phase may be useful.—*James C. Moore, M.D.*

Neck and Chest

MacEwan, D. W., Dunbar, J. S., and Murphy, D. R. Isolated tracheoesophageal fistula demonstrated by cinefluorography. *J. Canad. Ass. Radiol.*, Dec., 1960, *11*, 84–88. (From: The Montreal Children's Hospital, Montreal, Quebec, Canada.)

The authors present 2 cases of tracheoesophageal fistula. These patients were studied carefully and repeatedly before the proper diagnosis was made and treatment instituted. The positions of the tracheoesophageal fistulae, which were high in the neck, made the demonstration difficult, but diagnosis was possible by use of cinefluorography.

The usual clinical features are coughing, choking, and cyanosis after feeding in the newborn. Excessive mucus in the nose and pharynx is likely. Air which has entered the esophagus through the fistula may distend the abdomen. Pneumonia occurs frequently because of passage of food and secretions into the trachea. The fistula characteristically has a lower esophageal than tracheal orifice. The diameter of the lumen may vary from the size of a pinhead to several millimeters.

The higher the level of the fistula and the smaller its lumen, the greater is the difficulty of demonstrating it. The rapid pharyngeal and upper esophageal movements while swallowing, coupled with the coughing usually present, contribute to failure of visualization by fluoroscopy and spot films. The advantages of the cine method with slow motion or single frame analysis are evident.

Briefly the method of examination is: (1) an infant should first be investigated roentgenologically by catheterization of the esophagus and direct injection into the lower, then mid, and finally the upper esophagus, preferably using dionosil; (2) the injection should be done gently but rapidly so as to distend the esophagus; and (3) if no contrast medium enters the trachea by the above method, barium should be given by mouth and the swallowing mechanism observed.—*David C. Alftine, M.D.*

Batt, Harold D. Wandering of the retrocardiac esophagus: a pitfall in the diagnosis of left atrial enlargement. *Radiology*, April, 1960, *74*, 588–592. (Address: Hospital of St. Raphael, New Haven 11, Conn.)

Normal mobility of the esophagus may be confirmed by observing the pendulous motion of its distal portion during roentgen examination. In the frontal projection, on deep inspiration, the esophagus descends in a straight line, and on expiration it is commonly displaced slightly to the right of the midline by the normal left auricle. The author states that, when the retrocardiac esophagus is exceedingly mobile, it may be mistaken for an abnormal deviation secondary to left atrial enlargement.

The author presents 4 cases. In 1, the initial examination revealed the esophagus to be displaced posteriorly and to the right. This displacement was thought to be a result of left atrial enlargement. On subsequent examination, this diagnosis was proved erroneous, as the distal esophagus was found to be exceedingly mobile. It could be displaced to either side of the midline by turning the patient on one side or the other in the supine position. The second case is presented because of similar findings. Left lateral deviation of the esophagus was limited by the descending aorta. There was no atrial enlargement in these 2 patients. In the other 2 cases there was clinical evidence of left atrial enlargement. The roentgenographic examination revealed that the esophagus could be displaced to the right or the left by positioning the patient. Therefore, when the esophagus is very mobile and can be displaced to either side of the midline, the usual diagnostic criteria pertaining to its displacement by an enlarged left atrium must be applied critically and correlated with the clinical data.

This observation was probably first reported by Rösler and Weiss who attempted to produce by positioning right posterior displacement of the esophagus in patients with rheumatoid heart disease and left atrial enlargement. This was possible in only 1 of the 6 patients examined. Recently, 3 similar cases have been reported by other investigators. Also, unusual esophageal motility has been reported by Segers and Brombart in 2 cases of ectatic aorta, and by Hutton in 1 case of left atrial enlargement in an infant, secondary to congenital heart disease.—*W. M. McBride, M.D.*

Varadarajan, M. G. Carcinoma of the oesophagus with an unusual secondary in the subcutaneous tissues of the right orbit. *Mediscope*, Oct., 1960, *3*, 1–3. (From: The Government General Hospital, Madras, India.)

The fact that carcinoma of the esophagus spreads by the usual three routes—direct, lymphatic, and blood vessels—is pointed out by the author. The hematogenous metastases generally occur late in about one-third of the fatal cases.

A case with presenting symptoms of proptosis and loss of vision in the right eye is described. These symptoms were caused by a proved metastatic lesion from a relatively asymptomatic carcinoma of the esophagus. Palpable lymph nodes were also present in the suprasternal and supraclavicular regions.—*George A. Miller, M.D.*

Málek, P., Belán, A., and Kolc, J. Der Ductus thoracicus in der Röntgenkinematographie; Experimentalstudie. (Visualization of the thoracic duct by means of roentgen cinematography; experimental study.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, Dec., 1960, *93*, 723–730. (From: Institut für klinische und experimentelle Chirurgie, Prag, Czechoslovakia.)

The thoracic duct of dogs was visualized by means of roentgen cinematography, using lipiodol F as contrast material.

The following problems were studied: (1) the possibility of continuous filling of the thoracic duct; (2) the mode of emptying of the contrast material from the duct into the venous circulation; (3) the effect of diaphragmatic movement on the flow of the opaque medium in the duct; and (4) the effect of arterial pulsation on the duct.

Two main disadvantages to using this method clinically were encountered: (1) lipiodol is an oily contrast material; therefore, the danger of fat embolism exists after its injection into a closed system; and (2) in dogs the contrast medium has to pass only two lymph node groups before reaching the duct after it has been injected into the lower extremity; therefore, it can be introduced into the duct under sufficient pressure. Such favorable anatomy does not exist in the human being.—*Eckart Schackow, M.D.*

Longin, F. Über die lokalisierte und einseitige "helle Lunge." (Localized, one-sided radiolucent lung.) *Fortschr. a.d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, Dec., 1960, *93*, 673–687. (Address: Rö.-Abt. der Univ.-

Poliklinik, Klinikgasse 8, Würzburg, Germany.)

A classification of the causes of unilateral increased radiolucency of the lung is suggested. Isolated pulmonary artery hypoplasia and hypoplasia occurring with congenital cardiac defects are differentiated from unilateral emphysema with pulmonary artery hypoplasia. One case of the latter is presented. The pathogenetic relationship between this type of emphysema, the chronic essential emphysema and the nonobstructive emphysema of childhood is discussed. The hypoplasia of the pulmonary artery system observed in these cases is considered to be secondary to the pulmonary changes.

Reference is made to the circumscribed areas of increased radiolucency. Bronchostenosis or vascular changes are considered to be the causes. No possibility was seen of differentiating roentgenographically between the two etiologies. Therefore, it seems advisable to the author to avoid the terms "progressive lung dystrophy" and "degenerative lung disease," which imply a form of emphysema due to vascular causes.—*Eckart Schackow, M.D.*

Ormond, Robert S., and Poznanski, Andrew K. Pulmonary veins in rheumatic heart disease. *Radiology*, April, 1960, *74*, 542–549. (Address: R. S. Ormond, Henry Ford Hospital, Detroit 2, Mich.)

The posteroanterior roentgenograms of 172 patients who had undergone cardiac catheterization were studied to evaluate the pulmonary veins. In 107 patients, percutaneous left atrial heart catheterization was done and routine upright posteroanterior roentgenograms were taken within forty-eight hours thereafter. Sixty of this group were subsequently operated upon for correction of valvular defects. In a second group of 65 patients, laminagrams of the right pulmonary vasculature in the upright position were obtained. Of these patients, 50 had percutaneous left atrial catheterization and 25 had right heart catheterization. Seventeen patients of this group had subsequent cardiac surgery.

The study was confined to evaluation of the pulmonary venous changes in rheumatic valvular heart disease. The appearance of the pulmonary veins in the posteroanterior roentgenogram was found to reflect pressure changes in the left atrium. Upper lobe veins were found to be a reliable index to elevated pressure, responding to increased pressure by an increase in size. The veins were classified according to size. Patients with the largest veins were found to have pressures above 20 mm. of mercury; the intermediate group had pressures between 15 and 25 mm., and patients with the smallest veins had pressures below 15 mm. No appreciable difference in appearance was observed in lesions producing an elevated pressure.

The venous channels in the lower lung field are subject to some variation, but the superior basilar division of the inferior pulmonary vein is a fairly constant structure. Two points on this vein were selected for measurement: (1) approximately 1 cm. proximal to the left atrium and just distal to the first division of the vein, and (2) in the peripheral lung field just proximal to the last major division of the vein. The size of the lower lobe veins was found to be a less reliable index to elevated pressure than upper lobe vein size. In the presence of congestive failure, the veins in the lower lobes were found to be disproportionately enlarged.—*Arno W. Sommer, M.D.*

Klatte, Eugene C., Campbell, John A., and Lurie, Paul R. Aortic configuration in congenital heart disease. *Radiology*, April, 1960, *74*, 555–556. (Address: E. C. Klatte, 1100 W. Michigan Ave., Indianapolis 7, Ind.)

The authors have reviewed the plain roentgenograms of 610 cases of 12 commonly encountered lesions of congenital heart disease and have correlated the findings with well over 600 angiocardiograms. They found that aortic configuration was the key to recognition and differentiation of many primary types of congenital and acquired heart disease. It should be remembered that adults and children have different aortic configurations and, as a patient ages, there are continuous degenerative changes in the aortic wall so that there is a relative increase in aortic size. If the normal gradual increase is taken into consideration, the aortic size can be closely related to the volume and pressure of the blood entering the systemic circulation.

In left to right shunts, the aortic configuration is valuable in differentiating patent ductus arteriosus from systemic pulmonary shunts, such as atrial and ventricular septal defects and anomalous pulmonary venous return. A patent ductus produces an enlarged aorta and a convex bulging on the lateral margin of the aorta immediately below the knob. The enlargement is due to increased blood flow proximal to the shunt, while the convex bulge is due to localized tenting at the site of the ductus. As a rule, the systemic pulmonary shunts are not associated with enlargement of the aorta.

The aorta is usually enlarged in the tetralogy of Fallot and in tricuspid atresia without transposition of the great vessels. In the tetralogy, blood from both ventricles enters the aorta due to the pulmonary stenosis and the incomplete ventricular septum. Although the aorta often is enlarged in tricuspid atresia without transposition, it is frequently small when there is associated transposition. The authors state that aortic size has been the best diagnostic aid in differentiating these two conditions.

The aorta is decreased in size in truncus arteriosus,

where only a single vessel leaves the heart, and in transposition of the great vessels, pulmonary stenosis and fibroelastosis. In transposition, the aorta curves posteriorly in a wide curve in the sagittal plane, while in pulmonary stenosis the small size is due to decreased blood flow. Fibroelastosis produces poor ventricular contractions with a decreased cardiac output and, as a result, the aorta is small.

The aortic configuration in coarctation and aortic stenosis may be sufficiently characteristic to permit roentgen identification. With aortic stenosis there is dilatation of the ascending aorta which, on fluoroscopy, shows a typical systolic thrust. This thrust does not extend into the transverse or descending aorta unless there is associated aortic insufficiency. In coarctation, the ascending aorta is usually large but the transverse aorta is narrowed. As a result, a normal knob is rarely observed. The left subclavian artery is frequently enlarged and may mimic a normal knob if it arises from a lower and more medial position than normal. The innominate artery also is frequently enlarged and, with the enlarged left subclavian artery, widens the mediastinum.—*Edward B. Best, M.D.*

Jorgens, Joseph, Blank, Norman, and Wilcox, William A. The cinefluorographic detection and recording of calcifications within the heart; results of 803 examinations. *Radiology*, April, 1960, *74*, 550–554. (Address: J. Jorgens, 176 Taylor Ave., Fort Snelling, St. Paul 11, Minn.)

The authors describe the method of cinefluorography which they use in order to detect and localize calcific deposits in the heart. During the last two years, 803 cinefluorographic examinations were performed at the Minneapolis Veterans Administration Hospital. Most of the patients were males, between the ages of forty and seventy, who had been referred because of their cardiac symptoms. The accuracy of the cinefluorographic findings was corroborated in many instances at autopsy.

Calcifications were discovered and localized as follows: left coronary artery, 225; right coronary artery, 58; combined coronary arteries, 38; ascending arch of aorta, 21; pulmonary artery, 1; mitral valve including annular area, 89; aortic valve, 103; aortic annulus only, 3; combination of valves, 22; myocardium, 10; pericardium, 10; uncertain location, 11.

The entire examination consists of 6 film sequences, each one taken of a certain portion of the heart, with the patient in various positions. The total radiation exposure to each patient is about 20 r in air, delivered to a constantly changing skin field through a portal 4.75 inches in diameter.

Accurate localization of any calcification in the heart is of importance to the surgeon who is contemplating commissurotomy as it will aid him in his approach. It is the authors' opinion that cinefluorography is now the method of choice for detecting and localizing cardiac calcification.—*Donald N. Dysart, M.D.*

Patel, C. V., and Anand, A. L. A fatal case of pneumopericardium; probably due to a patent pleuropericardial defect. *Radiology*, April, 1960, *74*, 626–627. (Address: C. V. Patel, Khushaldas J. Mehta TB Hospital, Amargadh. via Songadh [Saurashtra], India.)

Pneumopericardium is usually associated with a congenital pericardial defect, which is most commonly located in the deep or "transverse sinus" and is the result of a too rapid growth of the lung bud, with an abnormal dilatation of the iter venosum of Lockwood. A defect may also be found with abnormalities of the great vessels or ectopic lung segments.

The authors present 1 case of pneumopericardium which resulted from the rupture of a tuberculous pneumonic cavitation into the interlobar pleural space. With the formation of an interlobar hydropneumothorax, there was a leakage of air into the mediastinum. Subsequently, through a patent pleuropericardial foramen, the air entered the pericardial cavity. This was followed by a pyopneumothorax which proved fatal.

The diagnosis of air in the pericardium was obvious on roentgenographic examination as an air-filled sac encircling the cardiac silhouette. When there are lesser degrees of air present than in the case reported, it may be necessary to differentiate it from air in a mediastinal hernia. In pneumopericardium, air does not rise above the normal limits of the pericardium in the erect position. Also, in mediastinal hernia there is alteration in the size with inspiration and expiration.—*W. M. McBride, M.D.*

Abdomen

Cole, D. S. and Burcher, S. K. Accidental pneumatic rupture of esophagus and stomach. *Lancet*, Jan. 7, 1961, *1*, 24–25. (From: Green Lane Hospital and Auckland Public Hospital, New Zealand.)

The authors present 2 cases of accidental pneumatic rupture of the foregut—1 of the esophagus and 1 of the stomach. The case of rupture of the esophagus was due to the accidental discharge of a fire extinguisher in the face of a man while he was talking; the rupture of the stomach occurred in an infant during the administration of O_2 via an intraoral catheter.

As to the mechanism of rupture in the first case, it was speculated that, with a sudden rise in pressure in the mouth, the pressure was transmitted to the laryngopharynx and the respiratory passages with reflex closure of the glottis. The air then forced open the cricopharyngeal sphincter and produced sudden distention of the esophagus. The cardia failed to re-

lax, as it does in the slower coordinated reflex of swallowing, and the dilated esophagus ruptured. However, if the pressure builds up gradually, as in the baby, both the cricopharyngeal and cardiac sphincters relax and the stomach distends and ruptures.

On the other hand, with a sudden rise in pressure at the lower end of the foregut, as in the incoordinate vomiting associated with spontaneous rupture of the esophagus and also in abdominal crush injuries, it is the cardia which gives way and the cricopharyngeal sphincter which fails to relax.

In both situations it is usually the lower left wall of the esophagus which ruptures, probably because it is less well supported in this area by surrounding structures.

In giving oral or nasal O_2 via a catheter, a second catheter should be used as a safety valve.—*William C. MacCarty, Jr., M.D.*

SMAREGLIA, M., FARACO, P., and BIANCO, A. Le neoplasie mesenchimali maligne del duodeno (contributo clinico-radiologico). (Malignant mesenchymal neoplasms of the duodenum [clinical and radiologic contribution].) *Ann. ital. di chir.*, July, 1960, *37*, 559–598. (From: Istituto di Clinica Chirurgica Generale e Terapia Chirurgica dell 'Università di Roma, Rome, Italy.)

A series of 6 cases of sarcoma of the duodenum is presented and the pathologic, clinical and roentgenologic findings are described.

From an analysis of the literature it is rather difficult to establish the real incidence of sarcoma of the duodenum, since in many cases the tumor is disseminated to other segments of the intestinal tract. In the opinion of the authors, to this date no more than 100 cases of sarcoma of the duodenum have been reported.

It is interesting to note that, in earlier publications, the incidence was equal in both sexes, while in the more recent literature it appears that males are more frequently affected than women. The lesion predominates in the second and third decades. The youngest of the patients here presented was nineteen years of age and the oldest fifty-one.

The most common sites are in the third and fourth portions of the duodenum, although very rarely the lesion stops at the level of the ligament of Treitz, and not infrequently the whole duodenal loop is involved. The neoplasm may grow into the lumen of the duodenum, may be intramural, or may extend externally. Two types are recognized—the infiltrating and the nodular type.

The clinical findings, as for all neoplasms of the small bowel, do not present any specific pattern and the symptoms are vague, at least initially. There may be dyspepsia, general malaise, loss of weight, anorexia and at times pain in the epigastric region. In the later stages an irregular elevation of temperature may appear with diarrhea and vomiting and, eventually, symptoms develop which are more specifically related to the type and site of the lesion and its complications, generally consisting of obstruction and ulceration.

The authors have classified this lesion into four types according to the main symptoms: (1) chronic stenosing type; (2) nonstenosing type; (3) icteric type; and (4) the type characterized by severe epigastric pain. The progress of the disease is divided in three periods: (1) latent period; (2) the period in which the clinical and physical findings become more definite; and (3) the period of "intoxication" which is related to the severely debilitated condition of the patient and the complications of the disease.

The roentgenologic findings in a sarcoma of the duodenum depend largely on the macroscopic appearance of the lesion, its site, and whether it is infiltrating or stenosing, limited or diffuse. Ferri and Roncorini have described different roentgenologic findings in accordance with the type of the lesion: (1) infiltrating type—the part of the duodenum involved appears rigid and of irregular caliber and the normal mucosal pattern is altered, with the possible presence of small filling defects; there are no peristaltic waves; (2) proliferative type—the lumen of the duodenum is increased; there are large filling defects and diminished elasticity of the walls is noted; the fine mucosal folds are replaced by gross tortuous plicae; ulcerations complicating this type of lesion are rare; and (3) mixed type—the filling defects are more evident; the walls of the involved duodenum are rigid and there is no peristalsis; the mucosal pattern is severely altered.

The gastric emptying time remains within normal limits unless the lesion involves the whole duodenal loop and there is a stenosis at the level of the upper third of the duodenum. One might, however, observe the pooling of contrast medium in the segment involved, even hours after the ingestion of the barium meal, due to the changes in the mucosal folds and, in particular, to the lack of peristalsis.

Another finding which has been described by several authors is presence of gas in the duodenum at the level of the distal third and/or at the duodenojejunal angle.

Cases have been reported also in which the only roentgen finding was a stenosis; while in others the only finding was an ulcerative process.

In the differential diagnosis one has to consider that fibrosarcoma, leiomyosarcoma, melanosarcoma and neurofibrosarcoma do not deeply infiltrate the duodenal walls. A tuberculous lesion of the duodenum and jejunum might resemble a sarcoma, but in the latter case there are no signs of retraction and of multiple fluid levels typical of the tuberculous process.

The treatment is surgical, either radical with com-

plete removal of the lesion or, in advanced cases, palliative. A course of roentgen therapy should always follow the surgical intervention. The end results are, however, not satisfactory.—*A. F. Govoni, M.D.*

Auguste, C., Tacquet, A., and Guerrin, F. Resultats du traitement du dumping syndrome par la transplantation duodénale de l'anse efferente. (Results of treatment of the dumping syndrome by duodenal transplantation of the efferent loop.) *Arch. mal. app. digest.*, 1960, *49*, 1103.

After discussing the characteristics which help to distinguish the dumping syndrome from other early syndromes which may be observed in gastrectomized patients, the authors present the results of duodenal transplantation of the efferent loop in 15 cases of intense and prolonged dumping syndrome.

Their conclusions are: (1) the corrective surgery is remarkably effective and the favorable result is observed as soon as feeding is begun. In the great majority of cases the postprandial symptoms disappear permanently; in a few they may persist or reappear in a very mild form; (2) the disappearance of the dumping syndrome is followed in half of the cases by an increase in weight and strength, and in some cases by an increase in sexual activity.

None of the patients operated upon, however, did fully regain the weight they had before gastrectomy. Although duodenal transplantation of the efferent loop greatly improves their condition, it is evidently unable to compensate for the loss of a portion of the stomach.

No recurrence of the ulcer was observed even in patients who previously had duodenal ulcer.—*Guy Albot, M.D.*

Epstein, Bernard S. Simple distal ileal obstruction. *Radiology*, April, 1960, *74*, 581–587. (Address: 270–05 76th Ave., New Hyde Park, L. I., N. Y.)

This study of the roentgenologic aspects of simple ileal obstruction was undertaken to assess the diagnostic value of scout roentgenograms and contrast examinations of the gastrointestinal tract. The symptoms in the 14 patients studied were often ill-defined and had been present for intervals varying from two weeks to more than seven years. These consisted of intermittent borborygmi, mild or sometimes severe abdominal cramps, nausea, distention, and occasional regurgitant vomiting. The severity of these symptoms depended upon the degree of obstruction and upon the rapidity of the block of the normal flow of bowel contents.

It was found that the scout roentgenograms did not always provide accurate information, as the findings were often normal when the ileal obstruction was not symptom-producing. When symptoms were present, a wide variation was found in the patterns of the small and large bowel, and both often contained considerable gas. In some patients, the gas and fluid distention of the ileum offered a clue to the diagnosis of distal small bowel obstruction.

Seven patients were studied with the use of a barium meal; 3 had both barium studies and examinations with water soluble contrast media, about 60 cc. of either hypaque or gastrografin taken orally; and 4 had examinations with the water soluble contrast medium only. Partial ileal obstruction was diagnosed when a water soluble medium was retained in the dilated distal small bowel for more than three hours, as this type of medium normally has a considerably more rapid transit time through the bowel than barium. These contrast studies permitted in some instances the accurate localization of the obstruction and identification of the various dilated loops of bowel. Either barium or water soluble contrast enema examinations were done in 7 patients when the oral studies did not permit a diagnosis.

All of the 14 patients were operated upon. The causes of the ileal obstruction were: adhesive bands and kinking due to adhesions in 5, stenotic ileitis in 5, neoplastic disease with extrinsic pressure and partial obstruction of the ileum in 3, and an intrinsic ileal carcinoma in 1. In most of the patients, the bowel proximal to the obstruction was found to be hypertrophic and dilated due to the slowly progressive block. In those with a more rapid clinical course leading to an unrelieved block, the bowel was dilated and thinned.

In general the clinical and roentgenologic identification of simple small bowel obstruction depends mainly on the location, rate of progression, and the persistence of the block. The author concludes that scout roentgenograms can be rather deceptive and that both barium studies and examinations with water soluble contrast media can be quite helpful in the investigations for ileal obstruction.—*Donald N. Dysart, M.D.*

Picard, R., Horeau, J., Guillon, J., Kerneis, J. P., and Robin, C. Réticulo-plasmocytome solitaire du méso-colon transverse avec amylose local et général. Guérison apparente deux ans après l'exérèse. (Solitary reticuloplasmocytoma of the transverse mesocolon with local and generalized amyloidosis. Apparent recovery two years after exeresis.) *Presse méd.*, 1960, *68*, 2002–2003. (Address: R. Picard, Clinique médical A du C.H.R. de Nantes, Nantes, France.)

The authors relate an exceptional case of solitary reticuloplasmocytoma without bone localization, without infiltration of the bone marrow by plasma cells, and without increase of serum-globulins. The

diagnosis was made only after exeresis of the tumor necessitated by frequent and abundant intestinal hemorrahges which could have been fatal for this twenty year old girl.

The histologic examination showed a local amyloidosis of the lymph nodes associated with amyloidosis of the spleen which was very enlarged, of the liver and of the kidneys.

Cytologically, the tumor was composed of mature and immature plasma cells and of young reticulum cells (hemohistioblasts). The plasma cells were especially numerous around areas of amyloidosis, indicating the part played by the pyrinophilic cells in the pathogenesis of amyloidosis.

Very few similar cases have been found in the literature. In the published cases a bone localization, an increase of serum globulins or an infiltration of bone marrow by plasma cells occurred only six to ten years after the onset of the disease. Therefore, some authors believe that this form of plasmocytoma is of a low grade malignancy, far less malignant than the classic Kahler's disease.

In the authors' case the recovery was spectacular after exeresis and persists now for 2 years and 9 months without amyloidosis. The patient has married and had a normal delivery in December, 1960. —*Guy Albot, M.D.*

FARRELL, THOMAS E., and WELDON, WILLIAM V. A comparative study of bunamiodyl (orabilex) and iopanoic acid (telepaque): a clinical report on 200 cases. *South. M. J.*, Jan., 1961, *54*, 54–56. (From: Radiology Service, Walter Reed General Hospital, Walter Reed Army Medical Center, Washington, D. C.)

Alternate patients were given 4.5 gm. of bunamiodyl (orabilex) and 3.0 gm. of iopanoic acid (telepaque). The number of patients showing side effects was significantly smaller with orabilex. The incidence of diarrhea was 9 per cent as opposed to 35 per cent with telepaque. Abdominal cramps occurred in only 6 per cent of the patients given orabilex as compared with an incidence of 25 per cent following telepaque. Orabilex causes less nausea and leaves less colonic residual, while producing slightly better visualization of the gallbladder and bile ducts.

The authors conclude that orabilex is the best of the currently available media for oral cholecystography.—*J. L. Williams, M.D.*

SHEHADI, WILLIAM H. Roentgenologic observations in cases of fistulae of biliary tract. *J.A.M.A.*, Dec., 1960, *174*, 2204–2208. (Address: 1348 Midland Avenue, Bronxville, New York.)

Fistulae of the biliary tract may be external or internal. With present-day standards of the practice of medicine and surgery, external biliary fistulae have become quite rare. They should present no special diagnostic problem as they can be readily recognized, and injection of a radiopaque contrast medium will outline the fistulous tract. Internal fistulae may be spontaneous or may follow biliary tract surgery.

The author reports on 18 cases of internal biliary fistulae, in all of which a characteristic gas pattern was observed in the biliary tract on routine roentgenograms of the abdomen. The presence of air in the biliary tract is considered unequivocal evidence of an abnormal communication between the biliary and gastrointestinal tracts. A rare exception to this is incompetence of the sphincter of Oddi. No differentiation can be made on the plain roentgenogram between spontaneous internal biliary tract fistulae and those due to other causes. Acute gaseous cholecystitis should not pose a problem in differential diagnosis, since in this condition gas is in the gallbladder and possibly in the cystic duct, to the exclusion of the hepatic and common bile ducts. Furthermore, the patient is acutely ill. With incompetence of the sphincter of Oddi, reflux of barium from the gastrointestinal tract usually occurs and outlines the biliary tract.

The finding of a "frothy" pattern of air in the upper portion of the liver is considered a characteristic finding in the presence of an abnormal communication between the biliary and gastrointestinal tracts. This usually occurs in the tertiary, or minute, biliary radicles, and rarely in the dependent radicles.—*Douglas S. Kellogg, M.D.*

PERILLI, L., and FANINI, E. Sulle calcificazioni pancreatiche studiate con la pneumostratipancreatografia. (Pneumostratigraphy of the pancreas in the study of pancreatic calcifications.) *Radiol. med.*, Sept., 1960, *46*, 834–842. (From: Ospedale Civile di Pescara, Italy.)

Pneumolaminagraphy of the pancreas, first described by Macarini and Oliva in 1957, consists of the visualization of the retroperitoneal spaces by presacral air insufflation, while the stomach is outlined by gas, following the ingestion by the patient of any carbonated beverage. Laminagrams are then taken with the patient in the anteroposterior and lateral positions.

Three cases are described and in 2 the roentgen findings were confirmed at surgery. The first case presented a single calcification which only after pneumolaminagraphy could be accurately located in relation to the superior border of the body of the pancreas. In the remaining 2 cases the calcifications were small and were diffused through almost the entire pancreas.—*A. F. Govoni, M.D.*

Gynecology and Obstetrics

Solish, G. I., Masterson, J. G., and Hellman, L. M. Pelvic arteriography in obstetrics. *Am. J. Obst. & Gynec.*, Jan., 1961, *81*, 57–66. (From: The State University of New York Downstate Medical Center and the Kings County Hospital, Brooklyn, N. Y.)

Pelvic arteriography was done on 20 obstetrical patients. The procedure was found to be of value in localization of the placenta in both intrauterine and extrauterine pregnancies and could be used to distinguish between the two. No complications occurred. Radiation exposure to the fetal area was not great.

The method used was percutaneous injection of the femoral artery on the side where the placental souffle was heard. Prior to the injection, pneumatic cuffs were placed around both thighs and were inflated to obliterate the dorsalis pedis pulse. Three serial arteriograms were generally taken at one second intervals starting just before completion of the injection of 20–50 ml. of 60 per cent renografin.

The placenta is identified by the appearance of the contrast medium in the intervillous space, giving a "cotton ball" configuration. At times, the coiled arteries may be seen entering these spaces. The extrauterine pregnancy is diagnosed by the absence of the spiral arteries leading to the placental sinuses and the independence of the coiled arteries in the small uterus from the placenta.—*George A. Miller, M.D.*

Bernstine, Richard L., Nelson, James H., Jr., Garcia, Nicholas A., III, Huston, J. Wilson, and Gartenlaub, Charles. Use of femoral arteriography in assessment of bleeding in pregnancy. *Am. J. Obst. & Gynec.*, Dec., 1960, *80*, 1161–1167. (From: Departments of Obstetrics and Gynecology and Radiology, United States Naval Hospital, St. Albans, N. Y.)

The use of percutaneous retrograde femoral arteriography has been studied for the past three years. The value of this technique in bleeding in all stages of pregnancy was recognized. As a result, an intense survey of all cases of bleeding in pregnancy over a six month period was made. The details of this survey serve as the basis of this article.

If no local cause of bleeding is found in those in the last half of pregnancy, a percutaneous retrograde femoral arteriography is done.

The femoral artery is injected at the inguinal ligament. Immediately prior to performance of the arteriography the pressure cuff is inflated well above systolic pressure and 30 cc. of the contrast material is injected as rapidly as possible (approximately within two seconds). The tourniquet is released immediately upon conclusion of the injection. Roentgenograms are obtained three and fifteen seconds after completion of the injection. If the placenta is seen to be low-lying on the anteroposterior projection, a second injection is made and a lateral film obtained at three seconds. The lateral projection gives more precise localization of the placenta.

The salient features are: (1) the determination of the presence of the placenta. In all the cases of this series, regardless of gestational age, it was possible to demonstrate placenta arteriographically; (2) the localization of the placenta. The accurate position and extent of the placenta can be determined by arteriography at all stages of pregnancy and regardless of fetal presentation. The authors use the anteroposterior roentgen projection to determine whether any portion of the placenta lies within the true pelvis. The lateral projection is used only to determine the exact localization of the placenta found within the true pelvis; (3) the determination of the presence of abruptio placentae. Prior to this study the diagnosis of abruptio placentae could only be inferred by clinical signs. During the course of this study, a previous isolated observation was confirmed, namely, pooling of contrast material in extravascular spaces. By pooling is meant a discrete oval accumulation of medium which is characteristically observed on the film exposed fifteen seconds after injection. This finding is to be distinguished from the irregular, patchy accumulations of medium seen three seconds after injection which are characteristic of placental sinusoids.—*Eugene J. McDonald, M.D.*

Visscher, R. D., and Baker, W. S., Jr. Isotope localization of placenta in suspected cases of placenta previa. *Am. J. Obst. & Gynec.*, Dec., 1960, *80*, 1154–1160. (From: Obstetrical and Gynecological Service, United States Naval Hospital, San Diego, Calif.)

The conservative management of placenta previa during the past few years has resulted in a substantial decrease in perinatal deaths that were attributed to premature delivery and resultant immaturity. This objective has been accomplished by allowing most patients to proceed in their pregnancy to as close to the thirty-eighth week of gestation as possible before actively interfering by vaginal examination to determine the presence of a low-lying placenta or placenta previa.

The patients selected for study are given 5 μc of radioiodinated human serum albumin in the antecubital vein. Care is taken so that neither the patient nor the operator is contaminated with radioactive material. A ten minute period is allowed for the isotope to mix thoroughly with the blood. During this time the abdominal surface over the gravid uterus is divided into 12 approximately equal sec-

tions. This is accomplished by measuring the height of the fundus above the symphysis and dividing this area into 4 equal horizontal parts. Each horizontal part is then divided into thirds, resulting in a total of 12 sections. A mark is placed in the center of each section, over which the counter is centered. The xyphoid process is also marked and this is used as a reference point.

A scintillation detector with a sodium iodide crystal and wide-angle aperture is used to detect the gamma radiation from the injected radioactive material.

The position of the placenta is described graphically and is stated to be in the fundus or lower segment and on the anterior or posterior wall. When the placenta is localized in the lower uterine segment, it cannot accurately be determined if it is a low-lying, partial, or total placenta previa.

The radioiodinated serum albumin is a commerical product readily available and relatively inexpensive. It has a half life of eight days and has to be renewed about every two to four weeks. The combined radioiodide protein molecule behaves biologically as the human serum albumin from which it is derived. This material mixes completely with the circulating blood within ten minutes. After one hour, appreciable amounts of the radioactive material start to mix with the extravascular fluid and also begin to undergo metabolic degradation. Therefore, the counts should be taken from ten minutes to one hour after the radioactive substance is injected into the vein.

Although the ultimate evaluation of the diagnostic reliability of this technique will depend upon more extensive clinical trials, preliminary study of 51 cases indicates that there has been a high degree of diagnostic accuracy. Placental site localization by this method proved to be 100 per cent accurate in all cases of repeat cesarean section and in patients in whom the placenta was localized in the lower uterine segment. The one equivocal result occurred in a patient with third trimester bleeding who was delivered vaginally.—*Eugene J. McDonald, M.D.*

Shoss, Milton, and Kratz, Paul E. Placental localization with use of radioactive iodinated human serum albumin. *Am. J. Obst. & Gynec.*, Dec., 1960, *80*, 1168–1172. (From: St. Francis Hospital, Cape Girardeau, Mo.)

The basis for the study and the use of radioactive iodinated human serum albumin is that the placenta represents a pool of blood where the isotope accumulates in quantities comparable to that in the heart as long as the isotope remains in the circulation. The material is injected intravenously and allowed to mix with the blood in the entire cardiovascular system, and counts are obtained over the various portions of the uterus as well as over the heart with use of a collimator attachment on a scintillation counter.

Counts were obtained over 12 areas outlined on the uterus. Counts were also obtained in the right and left flanks with the collimator almost perpendicular to the spine in both of these areas. These two areas for counting were thought to be of value in the localization of the placenta posteriorly.

The authors feel that this is a preliminary report which is not statistically valid because of the small number of cases. However, a trend is indicated. They feel this method has been shown to be sufficiently accurate, safe, and easy to justify as an addition to the armamentarium of the obstetrician. The test should complement but not replace existing methods of placental localization including roentgenographic examination. The one error in vertical localization has been partially explained and probably could have been avoided by the use of sufficiently active radioactive material.

Lateral localization was less than 50 per cent accurate but does not lessen the value of the procedure in determining placenta previa.—*Eugene J. McDonald, M.D.*

Genitourinary System

Fergusson, J. D., and Stevenson, J. J. X-ray television in urology. *Brit. J. Urol.*, Dec., 1960, *32*, 484–490. (From: St. Peter's, St. Paul's, and St. Philip's Hospitals, and Central Middlesex Hospital, London, England.)

The capability of directing an instrument during a surgical procedure to any part of the urogenital system which can be visualized roentgenographically has been achieved by linking a television camera and an image intensifier. The roentgen-ray image is transmitted to monitor screens in the x-ray department and operating theater. The localization and exploration of otherwise obscure urogenital lesions are made possible.

Suggested applications for this procedure are: routine retrograde pyelography; selective biopsy of roentgenographically demonstrated bone lesions as well as urologic lesions; diagnostic aspiration of "solitary" renal cysts; localization of small kidney stones at the time of operation; extraction of ureteric calculi; and implantation of radioactive gold or yttrium into the pituitary (in cases of advanced metastasizing cancer).—*William C. MacCarty, Jr., M.D.*

Pyrah, L. N., and Hodgkinson, A. Nephrocalcinosis. *Brit. J. Urol.*, Dec., 1960, *32*, 361–373. (From: Department of Urology, University of Leeds, and Metabolic Disturbances in Surgery Research Unit, General Infirmary at Leeds, England.)

In this paper, nephrocalcinosis is a strictly defined and limited diagnosis applied to roentgenographically visualized calcification in specific diseases. The calcium is found in or near the epithelial cells of the

collecting tubules and may ultimately form calyceal stones, causing clinical symptoms of pain and hematuria. Specifically ruled out as causes of nephrocalcinosis are such entities as diffuse laminar calculi found in infected kidneys, recumbency calculi secondary to spinal injury, dystrophic calcification of tuberculosis and dystrophic calculi secondary to polycystic kidney.

The authors include 76 cases of their own and 91 cases from a previously reported series (Mortensen and Emmett, 1954). The disease is bilateral in the great majority of cases (88 per cent) and may be found in either sex between the ages of twenty-one and fifty. The most common symptom was renal colic, with backache and hematuria less commonly reported. Often, voided calculi were the presenting symptom. In some cases, presenting symptoms were referable outside the urinary tract, such as pathologic fracture, ulcer, coma or paralysis. In about half of the cases, nephrocalcinosis was combined with the presence of an actual calyceal or pelvic stone.

It is suggested that these patients receive a complete general as well as urologic work-up, including roentgenography of the osseuos system, laboratory studies of the blood chemistry and evaluation of the diet in detail. Roentgen examination reveals spotty calcifications around the renal pyramids which may be associated with calculi and which vary in size according to the basic disease.

In the present series, the most common cause of nephrocalcinosis was found to be renal acidosis, with hyperparathyroidism as a close second. Other less common causes included pyelonephritis, milk-alkali syndrome, hyperoxaluria, and medullary sponge kidney. In the previous series (Mortensen and Emmett, 1954), hyperparathyroidism was by far the the most common cause, with acidosis second. In both series, a significant percentage of cases was classified as idiopathic.

Each entity is discussed in detail, with accompanying roentgenographic reproductions and tables. —*William C. MacCarty, Jr., M.D.*

Fleischner, Felix G., Bellman, Sven, and Henken, E. M. Papillary opacification in excretory urography; the so-called pyelotubular reflux. *Radiology*, April, 1960, *74*, 567–572. (Address: F. G. Fleischner, Beth Israel Hospital, 330 Brookline Ave., Boston 15, Mass.)

Various types of pyelorenal reflux have been observed during retrograde pyelography and have been termed pyelotubular, pyelovenous, pyelolymphatic, pyeloparenchymal, subcapsular, and peripelvic reflux. Only pyelotubular reflux is true backflow since the other types are the result of traumatic rupture. Within recent years similar types of reflux have been observed during excretory urography, without adequate explanation. One such type, supposedly due to pyelotubular reflux during excretory urography, presents a "brush-like" opacification of the renal papillae which gradually fades out toward the base of the pyramids.

The authors state that the explanations for dilatation of the tubules and stasis in the renal pelvis are inadequate and that the condition is not due to pyelotubular reflux. It can be explained, according to modern concepts of renal water metabolism, by final water resorption and concentration of urine in the collecting tubules and papillary ducts. Briefly, the kidney has been shown to have areas of equal osmotic pressure, arranged in concentric shells with the tip of the papillae as the central point of highest osmotic pressure. Therefore, these conditions in the papillary tissue provide a gradient for absorption of solute-free water from the collecting tubules.

These principles were corroborated experimentally by the use of hypaque injections in rabbits. After injection, the kidneys were removed, and microroentgenography of the sliced kidney showed greatest opacity in the papillae of the pyramid.

The authors conclude that the roentgen appearance of the so-called "brushes" is not a sign of a morbid condition but is rather a reflection of normal renal function.—*Edward B. Best, M.D.*

Evans, John A., Halpern, Mordecai, and Finby, Nathaniel. Diagnosis of kidney cancer; an analysis of 100 consecutive cases. *J.A.M.A.*, Jan. 21, 1961, *175*, 201–203. (From: Department of Radiology, the New York Hospital—Cornell Medical Center, New York, N. Y.)

Clinical, pathologic, and roentgenologic findings were correlated in 100 consecutive patients with primary renal cancer. In 97 patients the tumor was due to hypernephroma. The classic triad of hematuria, pain, and mass was present in only 10 to 15 per cent of the cases. Fifty-eight patients had gross hematuria and 15 had a palpable mass. Pain was present in less than 20 per cent. One-third of the patients had no clinical indications of renal disease. A Papanicolaou test of the urine was performed in 55 cases of hypernephroma and was negative for evidence of malignancy. Conventional roentgenographic studies were available in 91 patients and were entirely normal in 6. Fifty-eight patients had an enlarged kidney or a mass. Calyceal abnormality was seen in 60 patients and calcification was present in 7.

Conventional urographic studies were not reliable in differentiating between renal cyst and malignant tumor but nephrotomography enabled the authors to make the correct diagnosis in a high percentage of cases.—*J. L. Williams, M.D.*

Dollery, C. T. (London, England.) Detection of unilateral renal disease in hypertension

with diodrast ^{131}I. *Proc. Roy. Soc. Med.*, Nov., 1960, *53*, 969–972.

The author points out that the search for renal disease in patients presenting with hypertension is an important part of their investigation and is particularly rewarding when disease is discovered which is confined to one kidney. Reports of large series of patients with renal artery abnormalities causing hypertension have shown that more than one-half of these patients can be cured by nephrectomy or arterial reconstruction. However, finding them is a considerable problem in screening.

A considerable amount of work has been done by Winter and associates in the study of renal function using urographic contrast media labelled with I^{131}. In attempting to reproduce Winter's results, it was found that the curves recorded from the area of the right kidney usually showed a higher counting rate than those obtained from the left side and there was often only a small fall from the peak counting rate. This led to the suspicion that the liver might also concentrate the radioactive diodrast and contribute to the counting rate on the right side. A series of experiments showed that this was indeed the case. Various methods were tried in attempting to eliminate the liver background contribution, but none of the modifications tried entirely overcame it. The ideal solution to this problem would be a substance that was concentrated in the kidney but not in the liver. The use of I^{131} labelled hypaque is now advocated as there is apparently little uptake in the liver. This is an advantage, but it appears that this is more than out-weighed by errors in measurement which are inherent in such a slow concentration within the kidney, as is the case with hypaque.

The author believes that this technique is unsuitable as a screening test, but it is hoped that the use of other chemical compounds or alterations in technique may surmount some of the difficulties.—*Douglas S. Kellogg, M.D.*

Nervous System

Haft, Harold, Weinstein, Charles E., and Krueger, Erich G. Larger volume pantopaque lumbar myelography. *Radiology*, April, 1960, *74*, 605–610. (Address: H. Haft, 175 Eastern Parkway, Brooklyn, N. Y.)

The authors selected for lumbar myelography 30 patients who had clinical evidence of radiculitis involving the L-4, L-5 and S-1 spinal nerves. They were divided into 3 equal groups according to the quantity of pantopaque, 6, 9, or 12 cc., introduced into the subarachnoid space. The interval from the time of the first myelogram to completion of the examination, the time necessary to withdraw the medium, and the quantity of the medium remaining in the subarachnoid space were recorded.

These data demonstrated that the examination takes less time with larger volumes of the contrast medium; the quality of the myelograms is better diagnostically and technically; the medium may be removed more quickly and easily with less remaining in the subarachnoid space, causing less discomfort to the patient; and there is probably less radiation to the patient and the physician because of the shorter time required. This study indicates that 9 cc. is the optimum volume for lumbar contrast myelography. The authors believe that the generally held concept that volumes of pantopaque greater than 6 cc. should not be used is false.—*W. M. McBride, M.D.*

Skeletal System

Kessler, I., and Silberman, Z. Experimental study of radiocarpal joint by arthrography. *Surg., Gynec. & Obst.*, Jan., 1961, *112*, 33–40. (From: The Department of Traumatology, Central Clinic, "Zamenhoff," Tel-Aviv, Israel.)

This work is based upon a study of arthrograms of 60 wrists from anatomic specimens, and of arthrograms performed in 24 cases of various injuries in the wrist joint area. The study was made primarily with reference to the radiocarpal articulation or wrist joint. This is the joint between the proximal row of carpal bones and the articular surface of the radius in conjunction with the triangular fibrocartilage. From the anatomic point of view this joint is a separate one. Communication between the radiocarpal joint and the intercarpal joints is possible but is said to be a rare occurrence.

In two specimens a fresh tear appeared as a fissure and histologic examination revealed early degenerative changes in the cartilage. In some the form of the tear was round (showing persistence) and the histologic examination revealed advanced degenerative changes. In this study there was a communication between the radiocarpal and intercarpal joints in 4 of the 24 clinical cases, and in 9 of the 60 anatomic specimens. This is about the same percentage in both groups.

It is noted that thickening of the contrast line of the opaque medium injected in the respective place of a particular bone indicates damage of its articular surface. This will enable early diagnosis of post-traumatic intra-articular changes before they can be seen on simple roentgenograms.

Details of the technique of injection of the contrast medium into the radiocarpal joint are discussed, and reproductions of photographs and roentgenograms are included.—*Douglas S. Kellogg, M.D.*

Varadarajan, M. G., and Daniel, Arthur. Myositis ossificans progressiva. *Current Med. Prac.*, Oct., 1960, *4*, 520–528. (From: Barnard Institute of Radiology, the Government General Hospital, Madras, India.)

The roentgen studies of 3 cases of myositis ossificans progressiva are presented by the authors with the case report of 1.

The calcifications in the soft tissues in Case 1 were in the neck and thoracic areas; Case 11 showed calcification in the neck, axillae, and thoracic areas; and Case 111 showed calcification in the neck, right axilla, lumbar and thigh areas.

A thorough review of the possible clinical course, roentgen findings, and the differential diagnosis in myositis ossificans progressiva is given.—*George A. Miller, M.D.*

Blood and Lymph System

Tori, G., and Garusi, G. F. Ventricolografia cardiaca sinistra retrograda mediante cateterismo arterioso femorale percutaneo. (Retrograde left cardiac ventriculography by percutaneous femoral artery catheterization.) *Radiol. med.*, Sept., 1960, *46*, 801–823. (From: Istituti di Radiologia e del Radio della Università di Bologna, Italy.)

Retrograde arteriography of the heart using percutaneous arterial catheterization was first advocated by Peirce in 1951, but it was Seldinger who perfected a technique which, with minor changes, has now been generally adopted.

Satisfactory results obtained with this procedure are mainly reported in the French literature. In Italy, Tori and Garusi and in the United States Amplatz and his co-workers and Dotter also have adopted this procedure with satisfactory results.

The equipment and the technique are described in detail and the latter is more or less the one used by Dotter. The contrast medium (acetiodone 50 per cent or hypaque 50 per cent) is injected in the amount of 40 to 60 cc. by an automatic injector. Roentgenograms are taken using a Schönander biplane film changer with simultaneous exposure in the two sagittal planes at the rate of 2 to 4 films per second.

The indications for the use of the method and its results are discussed with particular emphasis on the roentgen demonstration and the evaluation of congenital or secondary abnormalities of the left side of the heart. Several roentgenograms show the value of the procedure in the visualization of patent ductus arteriosus, primary cardiomegaly, mitral insufficiency (simple or complicated), mitral stenosis with possible sclerosis of the aortic valve, aortic insufficiency, and aortic stenosis and insufficiency associated with mitral insufficiency.

In particular, the authors applied the procedure to 22 patients with mitral disease. Twelve were affected by mitral stenosis, confirmed by surgery. Of the 10 cases demonstrating stenosis and insufficiency, 5 were operated upon and the regurgitation was confirmed.

The conclusions reached by the authors are the same as those presented by Dotter. The method is "a reasonably safe, simple and effective procedure for obtaining detailed anatomic and physiologic information of investigative and clinical importance."—*A. F. Govoni, M.D.*

Grünert, R. D. Lebervenenkatheterung und Splenoportographie in der Diagnostik des portalen Hochdrucks. (Catheterization of the hepatic vein and splenoportography in portal hypertension.) *Chirurg*, Dec., 1960, *31*, 534–539. (From: Chirurgische Universitätsklinik, Abteilung für Thorax- und Herz-Gefässchirurgie, Göttingen, Germany.)

A report is given evaluating the results of catheterization of the hepatic vein and splenoportography on patients with portal hypertension. Often, the final diagnosis was made by using splenoportography and splenomanometry only. The method is simple and no post-examination hemorrhage was encountered.

Catheterization of the hepatic vein is of value for the differential diagnosis of liver diseases and is recommended under the following conditions: (1) if the spleen is inaccessible; (2) if the spleen has been removed; (3) if there is no demonstration of the portal system with splenoportography and if it is not clear whether this is due to a technical failure or to portal pathology; and (4) in combination with cardiac catheterization if the liver is enlarged and the presence of pericarditis constrictiva is suspected. Furthermore, a catheterization of the hepatic vein should be done in cases of a partial prehepatic block in order to determine whether there is hypertension beyond the point of constriction.

This report is based on catheterization of the hepatic vein in 45 patients.—*Eckart Schackow, M.D.*

General

Vuorinen, P., and Särkkä, E. Recording of the blurring effect due to the vibrations (lost motion) in a linear tomograph. *Radiology*, April, 1960, *74*, 628–632. (Address: P. Vuorinen, University Central Hospital, Turku, Finland.)

The authors present a method for studying the vibration (lost motion) phenomenon in a linear laminagraph (Siemens Universal Planigraph).

An electrokymograph with roentgen rays from the focal spot of the laminagraph tube and a radiosensitive photocell as a substitute for film was used to determine the blurring effect produced by the vibration (lost motion) of the machine. The longitudinal vibration and that perpendicular to it, transverse vibration, were both recorded. During the movement, longitudinal vibrations of only 0.5 to 0.6 mm. and transverse vibrations ranging from 0.4 to 0.5

mm. were recorded. Thus, no remarkable difference between the transverse and longitudinal vibration (lost motion) was observed. This is thought by the authors to be due to a real lost motion, such as that produced by the chains and toothed wheels of the driving mechanism, whereas the greater staggering in the longitudinal direction is due to true inertia.

The unintentional blurring due to this effect was believed to be insignificant in sturdily built machines. —*John S. Alexander, M.D.*

Gershon-Cohen, J., and Moore, Lolita. Roentgenography of giant fibroadenoma of the breast (cystosarcoma phylloides). *Radiology*, April, 1960, *74*, 619–625. (Address: J. Gershon-Cohen, York and Tabor Roads, Philadelphia 41, Pa.)

Cystosarcoma phylloides, a rare, giant form of intracanalicular fibroadenoma, usually occurs as a large, nodular, almost entirely encapsulated breast tumor. The authors discuss 9 such cases with the roentgenographic findings of each and they conclude that roentgenographic aid in the diagnosis of such tumors can be substantial but the findings are not pathognomonic.

On the roentgenogram, these tumors appear sharply outlined with smooth contours which may be lobulated. These masses must be differentiated from fibroadenomas, cysts, and circumscribed carcinomas. If flaky calcium deposits are seen in a discrete, uniformly dense mass, then the diagnosis of fibroadenoma is most likely. If a homogeneous mass has borders that are not sharp, and if the surrounding tissues are indistinct due to edema or infiltration, then the possibility of cancer must be entertained.

Since cystosarcoma phylloides is considered to be a benign condition, radical therapy is indicated only when malignant changes are found by the pathologist. The authors believe that such changes should also be looked for by the roentgenologist.—*John S. Alexander, M.D.*

RADIATION THERAPY

du Mesnil de Rochemont, R., and Lauth, G. Beitrag zur Klinik und Therapie des solitären und metastasierenden Bronchialkarzinoids. (The clinical picture and therapy of solitary and metastasizing bronchial carcinoids.) *Strahlentherapie*, Sept., 1960, *113*, 1–31. (From: Universitäts-Strahlenklinik und Poliklinik, Marburg/Lahn, Germany.)

The authors review 4 of their patients with bronchial carcinoid and they discuss the clinical picture and pathogenesis of solitary and metastasizing bronchial carcinoids. Endocrine effects occur with bronchial, as well as intestinal, carcinoids.

The treatment of choice is still early resection of the tumor. However, both the tumor and its metastases regress with adequate irradiation (4,500 r tumor dose). Cytostatic therapy alone is ineffective. The fate of the patient rests less on the benign histologic character of the tumor than on its local malignancy.—*Henry G. Moehring, M.D.*

Roswit, Bernard, Malsky, Stanley J., Reid, Cyprian, and Spreckels, Charles. The use of photocells for determination of patient movement during roentgen therapy. *Radiology*, Mar., 1960, *74*, 480–482. (Address: B. Roswit, VA Hospital, 130 W. Kingsbridge Road, Bronx 68, N. Y.)

In radical therapy of radiocurable cancer, it is imperative that complete immobility be maintained during exposure to the beam. A method for obtaining a graphic record of the patient's movement, and for continuous surveillance during therapy would be desirable. The authors devised a system which fulfills these requirements.

The method is simple and inexpensive, utilizing a miniature photocell, a light pipe, and a graphic recorder. Miniature photocells are mounted on a plaster treatment shell on the patient's body at two selected points at 90° to each other, with a light source in proximity to each photocell. Dual strip chart recorders are employed to plot the slightest displacement of the two selected reference points.

In actual practice the system has proved to be simple, relatively inexpensive, and entirely reliable. Schematic drawings of the system and charts illustrating its use are reproduced.—*Arno W. Sommer, M.D.*

Karzmark, C. J., Loevinger, R., Steele, R. E., and Weissbluth, M. A technique for large-field, superficial electron therapy. *Radiology*, April, 1960, *74*, 633–644. (Address: C. J. Karzmark, Stanford Medical Center, 300 Pasteur Drive, Palo Alto, Calif.)

Because the fall-off in depth dose near the end of the range of the electrons is particularly rapid for electron beams having energies less than about 10 mev., such beams are suitable for the treatment of widespread, superficial lesions, where it is desirable to minimize the dose to deep tissues. In addition, an acceptable uniformity of dose over the treatment area must be maintained; the accompanying supervoltage roentgen-ray background must be kept low; changeover from electron beam to roentgen therapy must be rapidly and conveniently accomplished; and the technique should not impose severe demands on the size of the therapy room or its arrangement.

Using the Stanford medical linear accelerator, a technique for large field, superficial electron beam therapy has been devised. The electron beam is brought out through an existing roentgen-ray defin-

ing system and then scattered by passage through a thin foil. The patient stands about 10 feet from the end of the accelerator, and the entire exposed surface is irradiated simultaneously by the broad electron beam. The treatment of a particular body surface consists of two parts—one with the axis of the accelerator directed above the patient's head and the other with the axis directed below the patient's feet. The combination of the two fields results in a highly uniform dose distribution over the entire height and width of the patient. The average roentgen-ray background dose to which the body is exposed is appreciably less than 1 per cent of the maximum electron dose. The conversion to and from electron therapy is simple and readily accomplished by therapy technicians in approximately five minutes.

The interested reader is referred to the original article for a detailed description of the apparatus used in changing from roentgen-ray operation to electron beam operation, or vice versa, including collimation and monitoring devices, considerations of energy loss and scattering, measurement techniques and dosimetry, depth dose and isodose distribution data, roentgen-ray background data, shielding, and effects of oblique incidence.—*Walter H. Jarvis, Jr., M.D.*

RADIOISOTOPES

Spafford, Norma R., Carr, Edward A., Jr., Lowrey, George H., and Beierwaltes, William H. I^{131} labeled triiodothyronine erythrocyte uptake of mothers and newborn infants. *Am. J. Dis. Child.*, Dec., 1960, *100*, 844–849. (From: Departments of Internal Medicine, Pharmacology, and Pediatrics, the Clinical Radioisotope Unit and the Thyroid Research Laboratory, University of Michigan Medical School, Ann Arbor, Mich.)

Eighty normal infants in the first seven days of life were the study group. No infant in this group had a family history of thyroid disease. Blood samples consisted of cord blood from 10 infants at delivery, and single femoral vein blood samples were drawn from each of the remaining 70 infants. Blood samples were drawn from 8 of the mothers. Erythrocyte uptake of I^{131} labeled triiodothyronine was performed by a minor modification of the method of Hamolsky *et al.*, and PBI and BEI values were obtained as well.

It was found that the mean PBI of the infants, 8.4 μg. per cent, and the mean BEI 7.0 μg. per cent, were virtually identical to maternal values. The mean T^3 erythrocyte uptake in infants at birth was 9.9 per cent with the range 6.6 to 15.1 per cent. The mean T^3 erythrocyte uptake of the mothers was 7.0 per cent. The highest value among the group of infants was found in the child of the mother who had the highest value among the group of mothers.

At 24 hours the mean T^3 erythrocyte uptake of the 80 infants had risen to 15.4 per cent, and thereafter it stayed well up in the normal adult range, with a mean at seven days of 14.3 per cent.

This test has the conspicuous advantage, among radioisotope tests to be used in infants, in that no radioactive material need be administered to the patient. Values are apparently independent of exogenously given iodine, which will invalidate the results of PBI or BEI determinations. The test has already been found to be a valid and useful one in many laboratories in dealing with adult thyroid problems, and will probably find wide application in thyroid disorders of infants and young children.—*Frederick J. Bonte, M.D.*

Thomas, I. D., Oddie, T. H., and Myhill, J. Diagnostic radioiodine uptake test in patients receiving antithyroid drugs. *J. Clin. Endocrinol. & Metab.*, Dec., 1960, *20*, 1601–1607. (From: Unit of Clinical Investigation, Royal North Shore Hospital of Sydney, Crows Nest, N.S.W., Australia.)

Thyroidal radioiodine uptake measured at 10 minutes appears to yield results as valid as those of the one hour uptake, and, although most laboratories do not calculate rate constants, as do the authors, several very interesting points are brought out. Chief among them is that results of the thyroid suppression test apparently remain valid even while the gland is blocked by the administration of an antithyroid drug such as propylthiouracil. If suppression is not demonstrated this can be taken to mean that the underlying disease state is still present, while, in a patient who has been on prolonged blocking drug therapy, a significant suppression of thyroid uptake may be taken to mean that a remission has occurred and that blocking drug therapy may be withdrawn.

The authors point out that performing a suppression test during blocking therapy reveals the underlying functional state of the thyroid gland as distinct from the level of hormone production, which is itself lowered as the result of successful treatment, and that the method may be used to identify compensatory gland hyperplasia due to overtreatment. It should be further noted that this test regime will not yield valid results if the uptake of iodine by the thyroid gland has been blocked by the administration of iodine or perchlorate.—*Frederick J. Bonte, M.D.*

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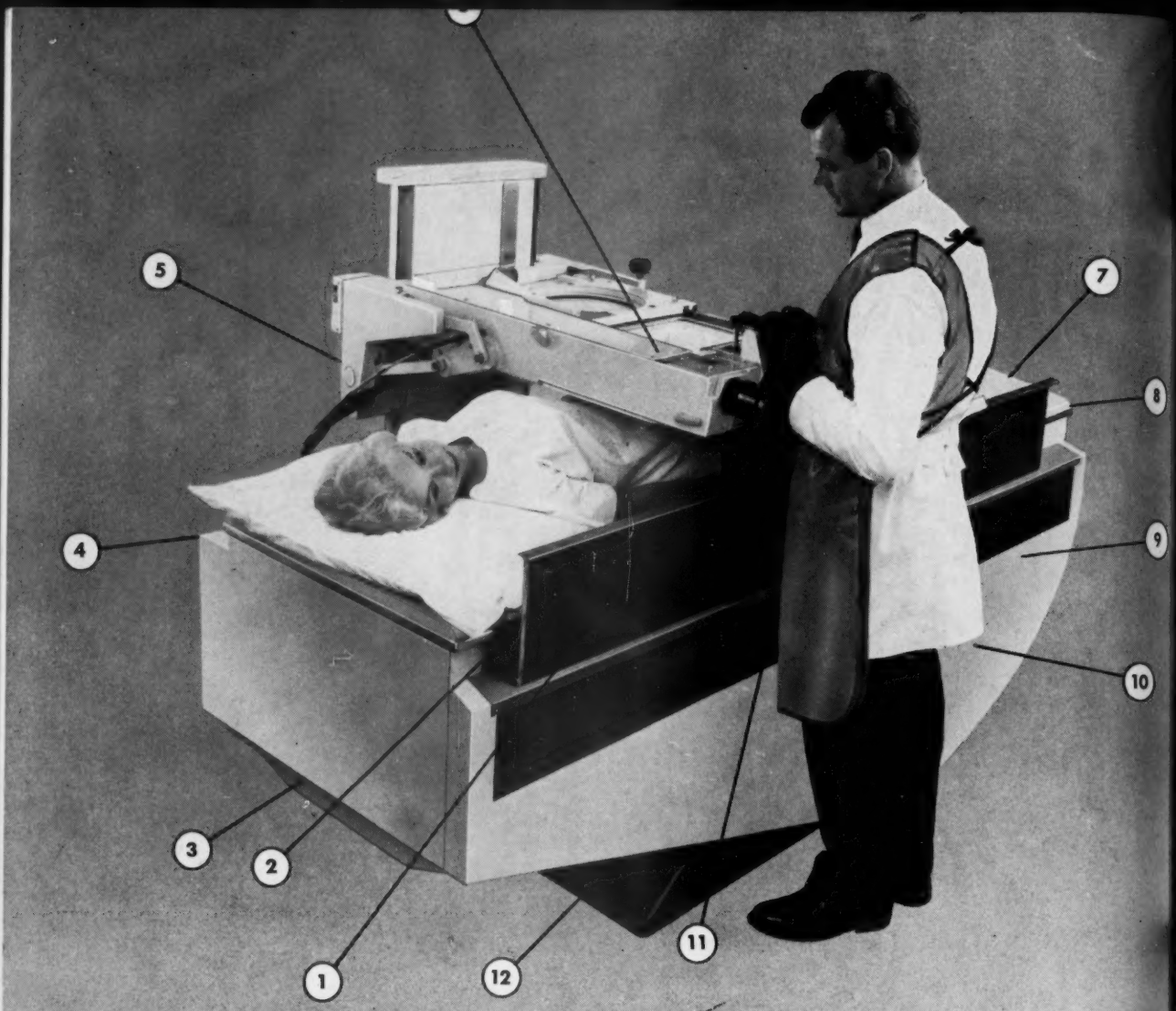

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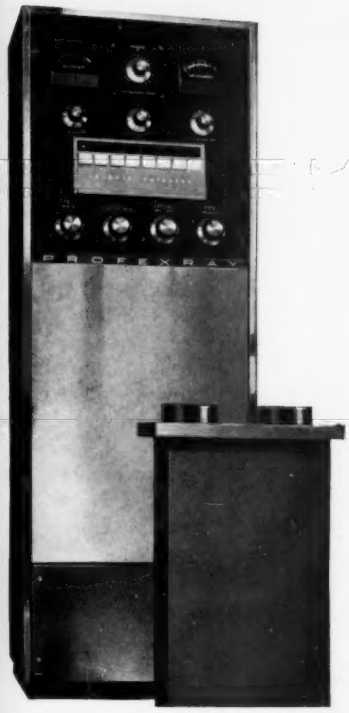

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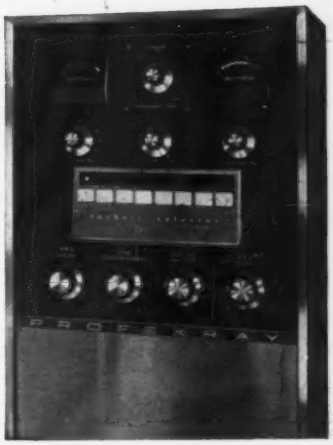

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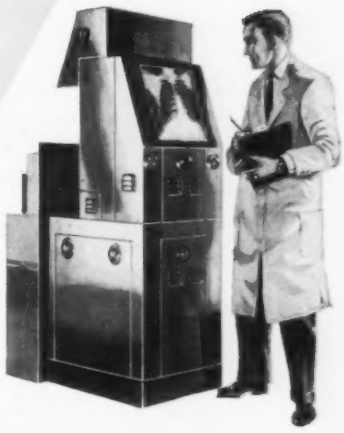

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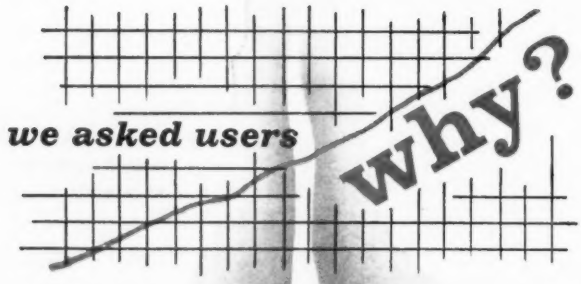

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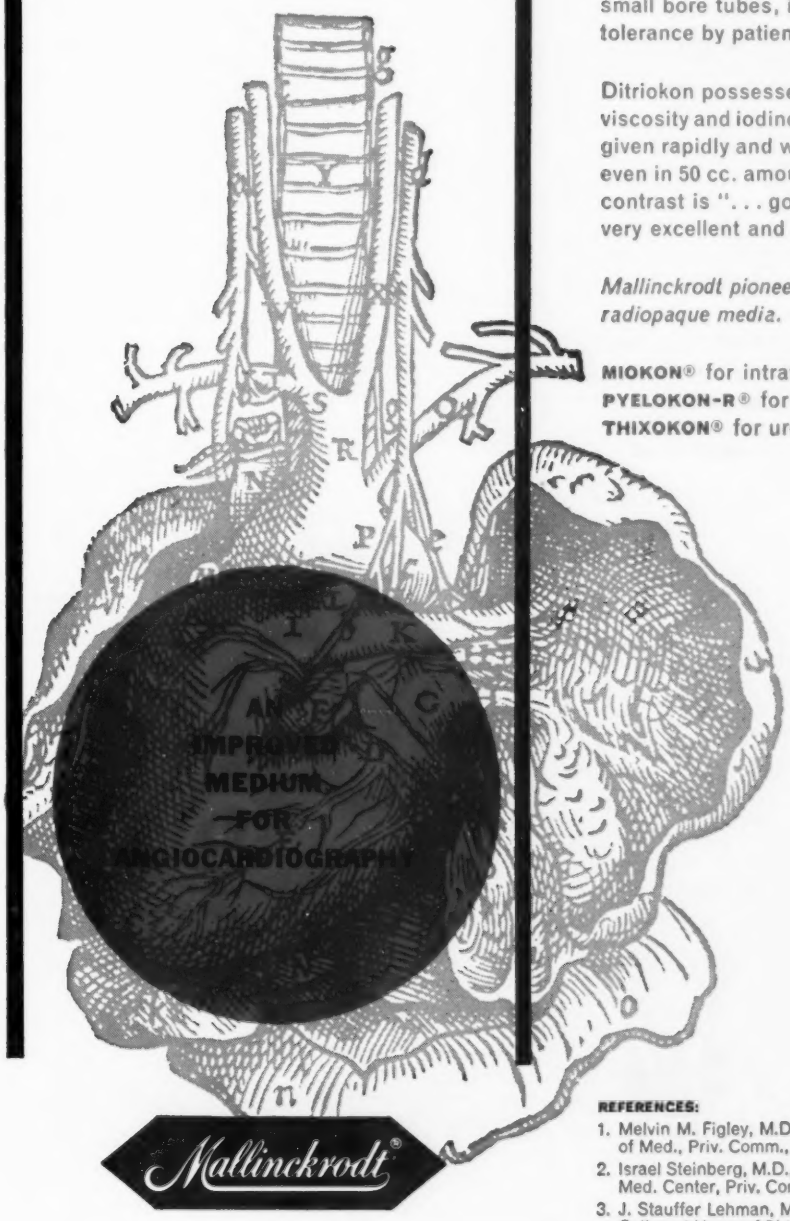

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2. Israel Steinberg, M.D., N.Y. Hosp. Cornell Med. Center, Priv. Comm., Oct., 1959.
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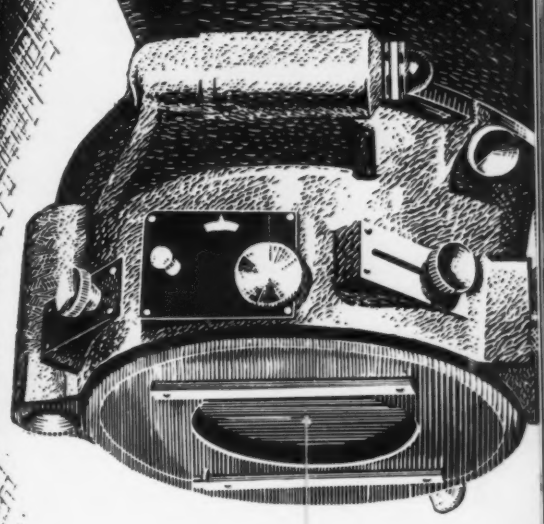

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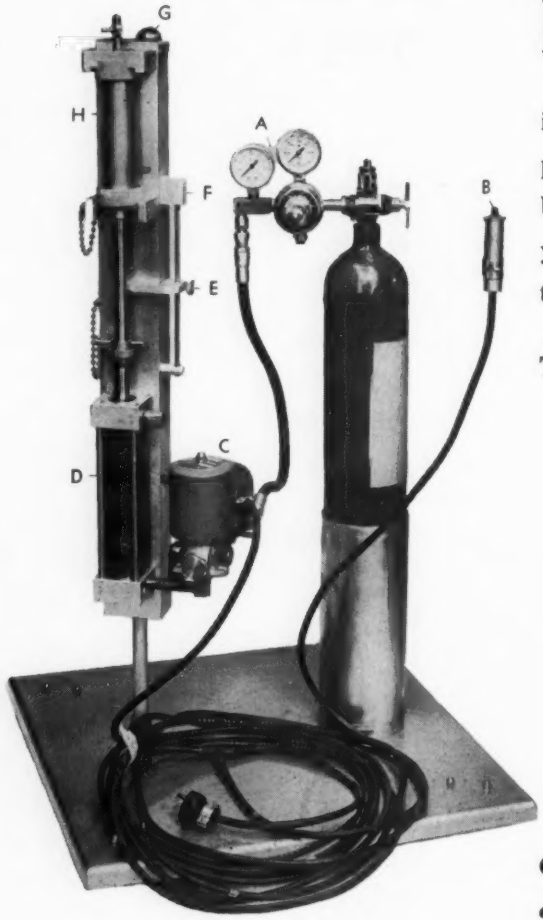

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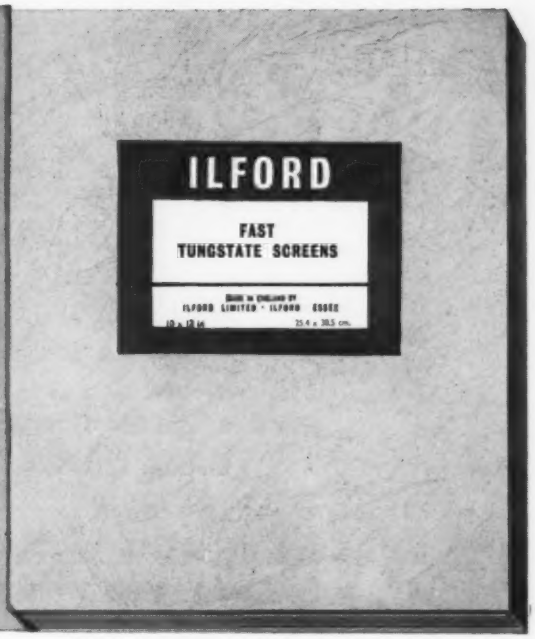

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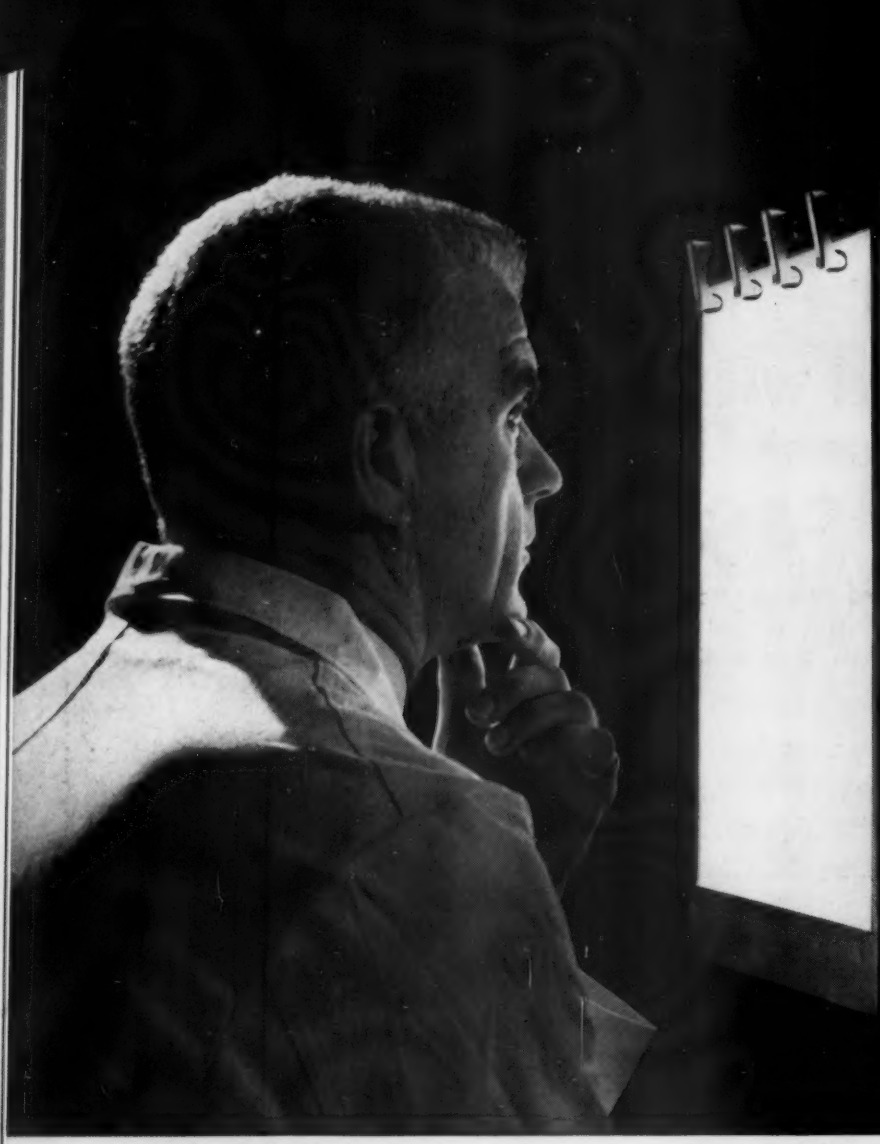

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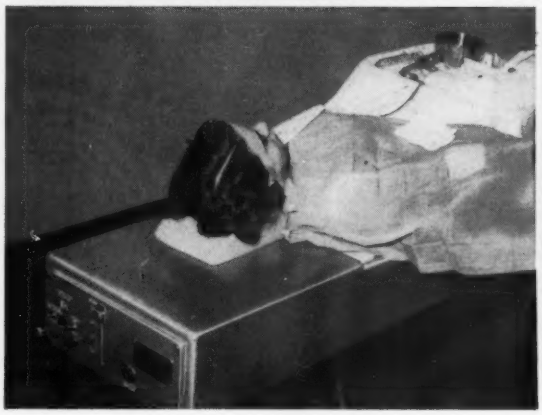

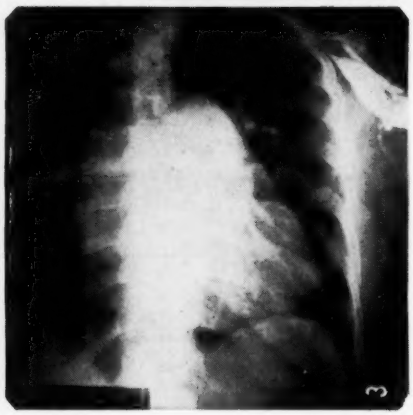

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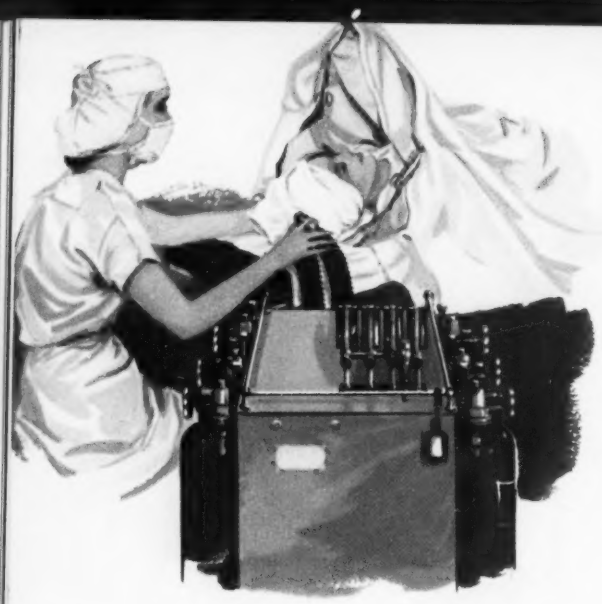

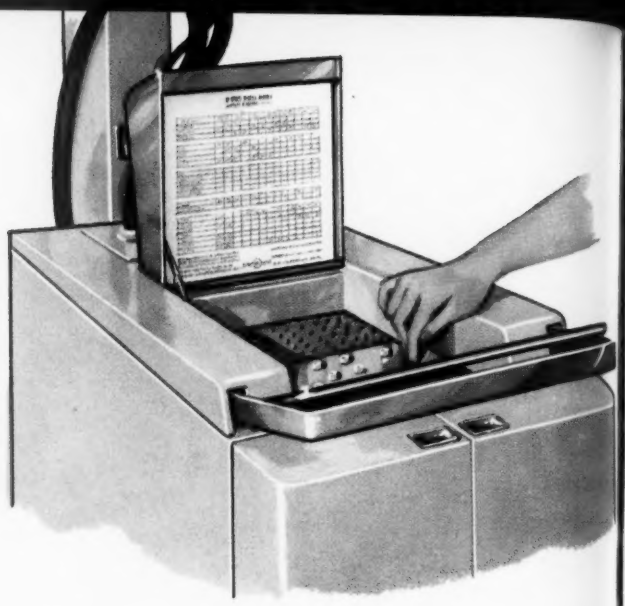

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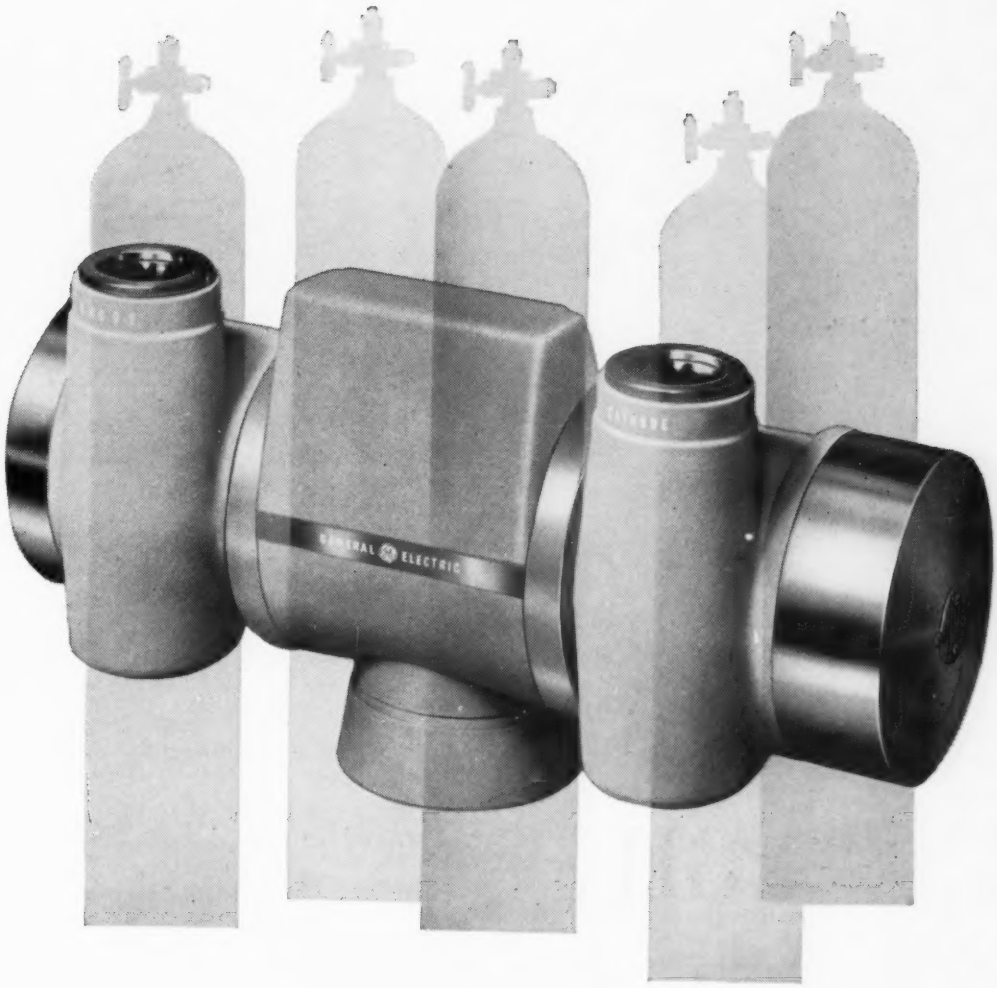

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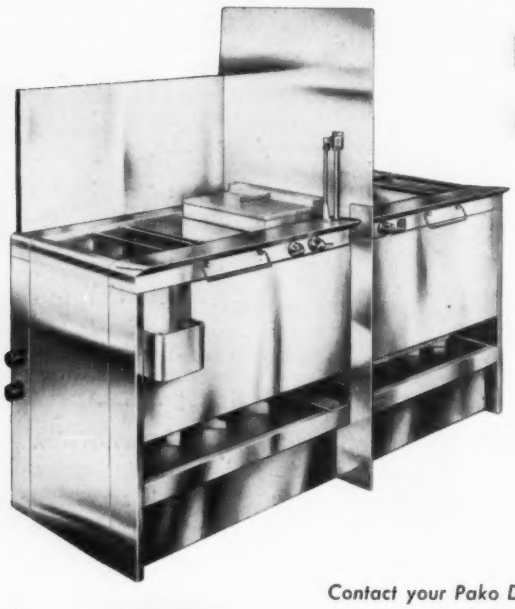

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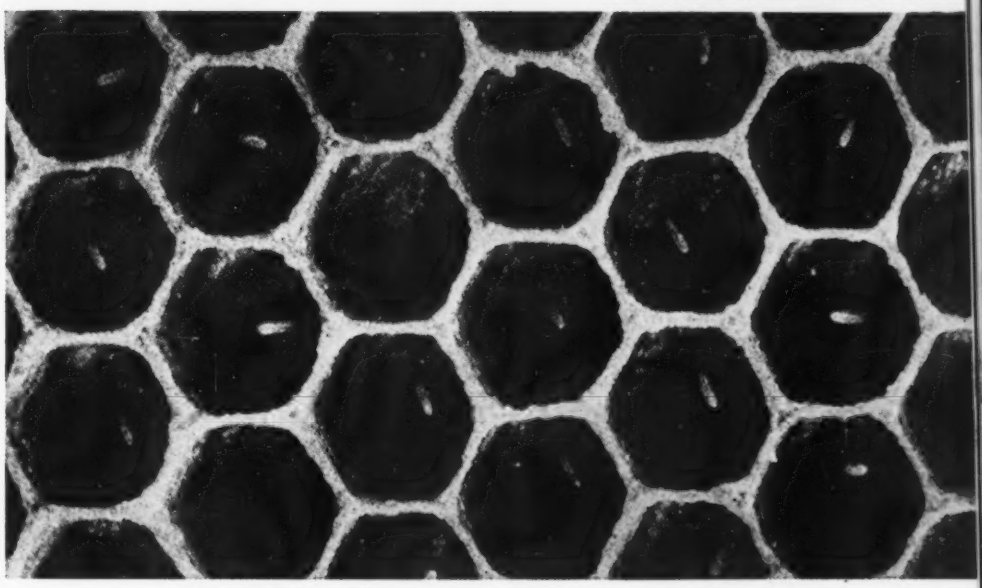

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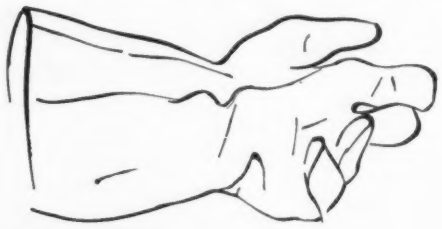

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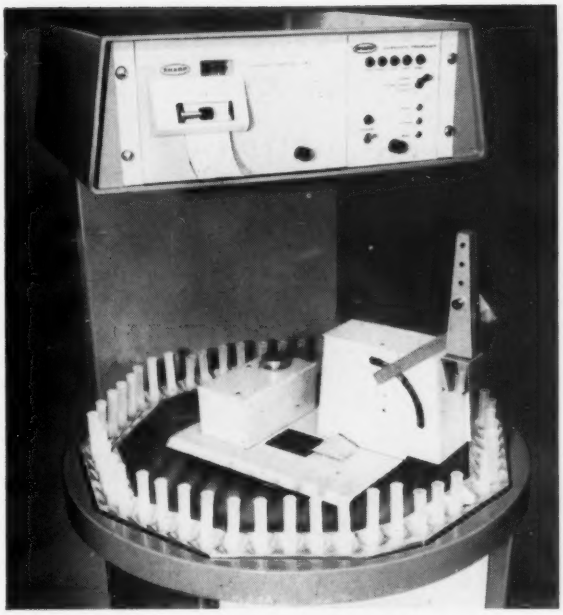

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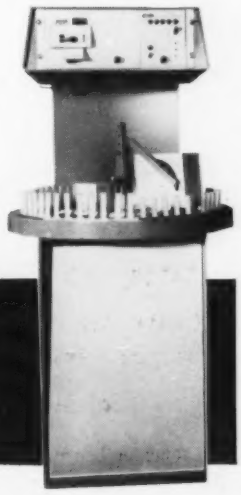

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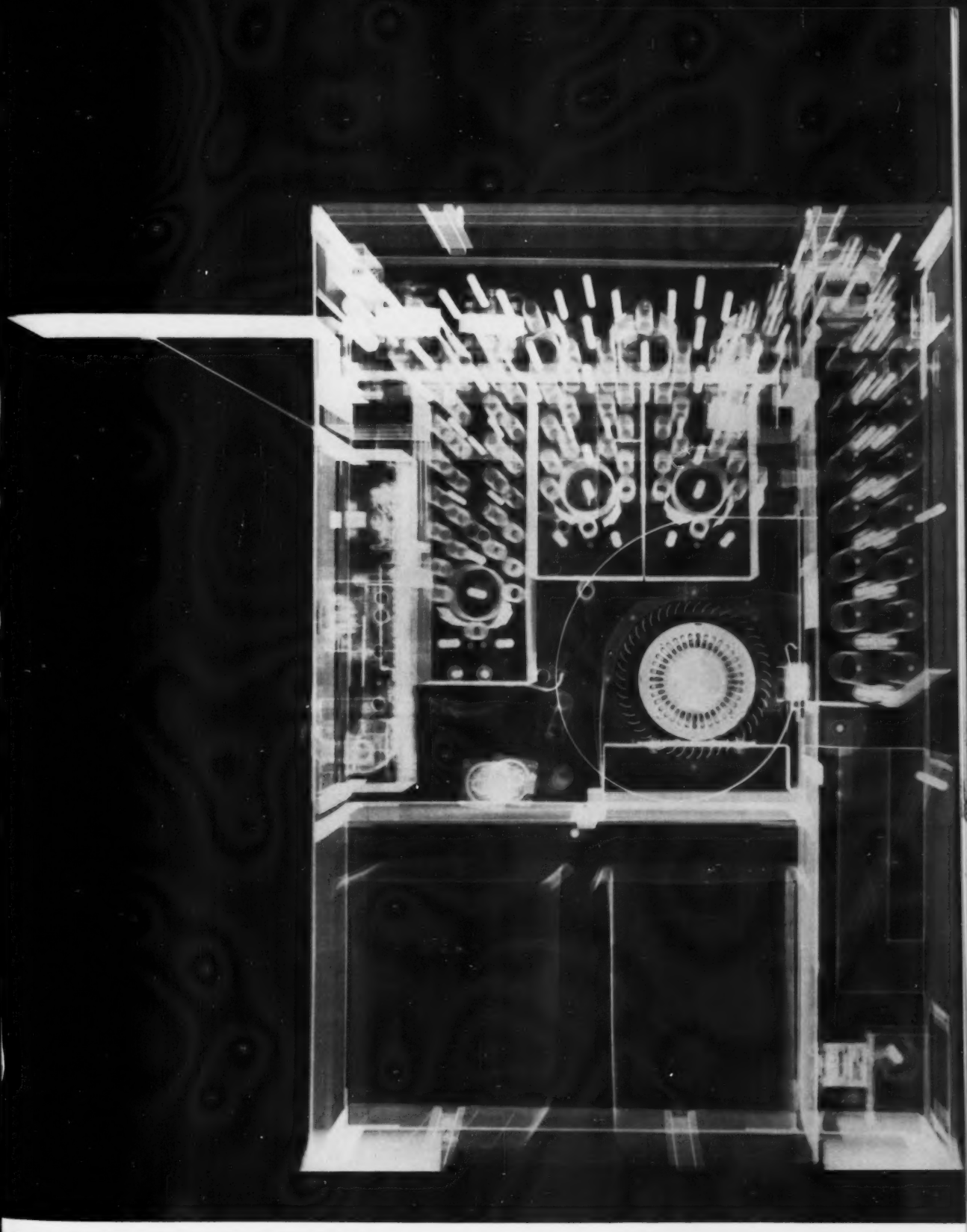

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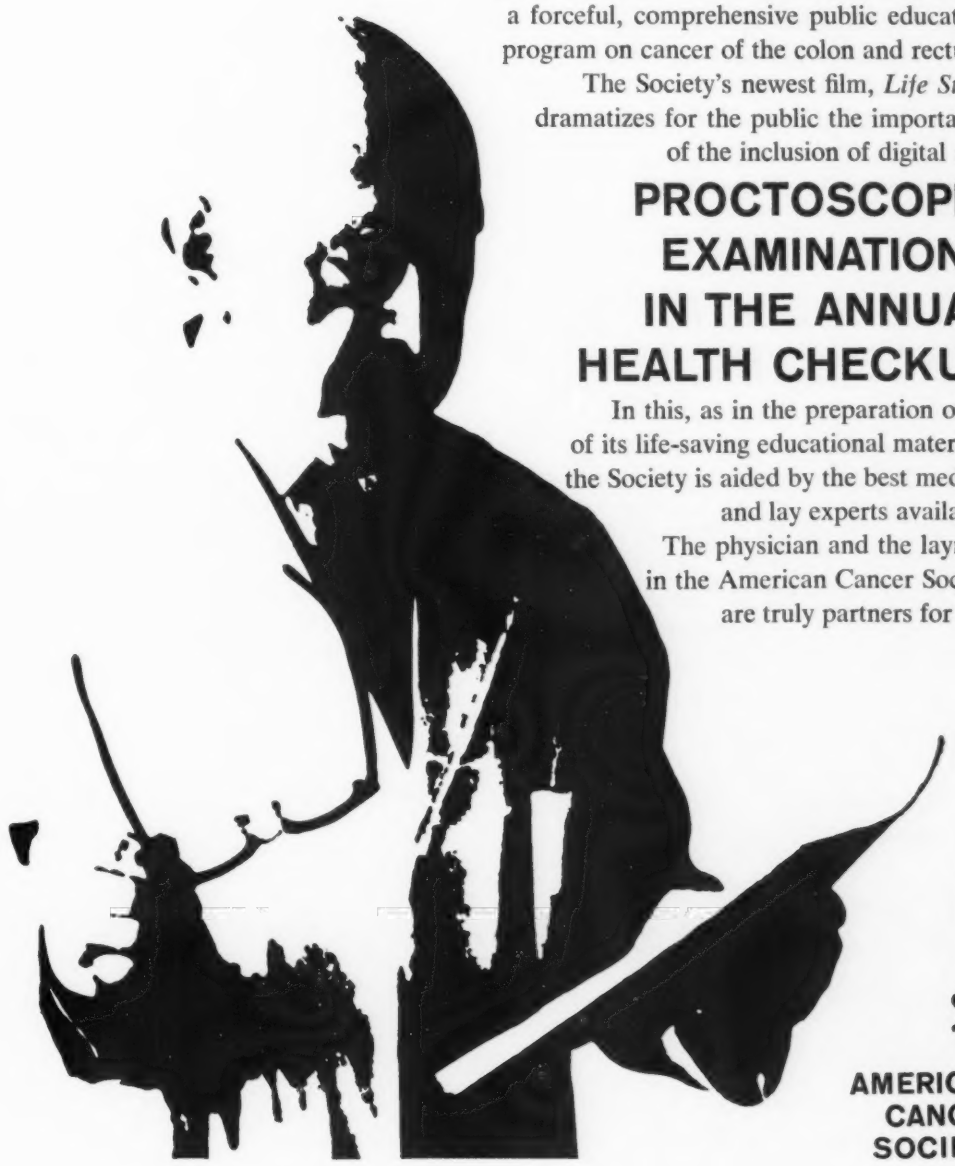

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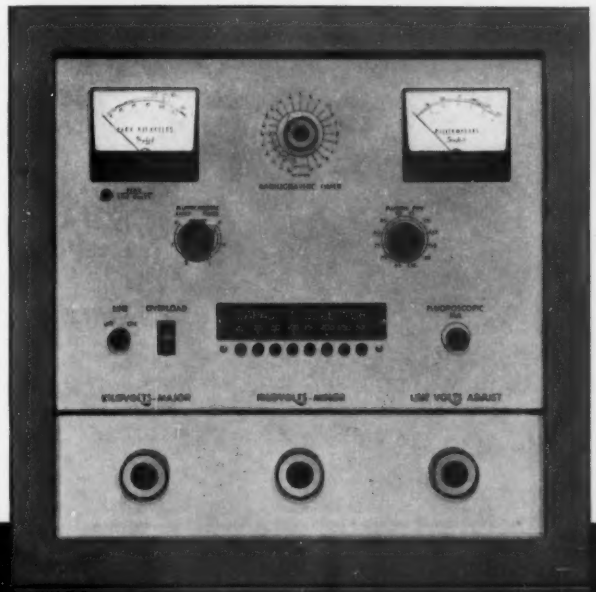

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